CAD and creativity at Key Stage 3 : towards a new pedagogy

Thesis

Link(s) to article on publisher's website:
http://dx.doi.org/doi:10.21954/ou.ro.0000d4f8

UNRESTRICTED

The Open University

CAD and Creativity at Key Stage 3: Towards a New Pedagogy

Deborah Winn

Thesis submitted in partial fulfilment of the requirements for the degree of a Doctor of Philosophy

January 2012

Department of Design, Development, Environment and Materials

DATE OF SUBMISSION: 5 JANUAY 2012

DATE OF AWARD: 8 NOVEMBER 2012

Contents

List of illustrations

List of tables

Acknowledgements

I would like to take this opportunity to express my gratitude to the many people who have contributed directly or indirectly to the completion of this thesis. In particular I wish to thank my supervisors Steve Garner and Frank Banks, who have probably exhausted their supply of red pens on my work over the years. Without their guidance, help and support I do not believe I would have completed the thesis and therefore owe them my very sincere gratitude.

I would also like to extend my gratitude to all the students and teachers who have participated in the research studies. In particular to Tim Hitch, former Principal at the school involved in most of the studies, for allowing me to combine my teaching role with my research and Richard Dunkley, Head of Design and Technology at the alternative school involved in the study, who went to great lengths to ensure he completed his part in one of the studies and who provided extremely helpful commentary; and for their invaluable advice and technical support Tim Brotherhood from PTC, the makers of *ProDesktop*, and Andrew Willetts.

I would like to offer special thanks to my dad, Michael Mayhew, who has always encouraged me and made me believe I could do anything if I worked hard enough, and to the rest of my family who have always been available for support and a cup of tea when needed. My friends have been invaluable and I would especially like to thank Jan Ward for her patience, help with the studies and the odd pint of beer over the past few years. Finally I would like to thank my husband, Matthew Winn, whose constant support and understanding has been immeasurable.

Abstract

In recent decades there has been a major shift in the Design and Technology curriculum in secondary schools away from manual techniques and towards digital processes and products. CAD/CAM (computer-aided design/computer-aided manufacturing) is not only commonplace it is also embedded into the English National Curriculum. There is much evidence to suggest that this shift of emphasis has not been without problems. The equipment used to design and quickly modify products mirrors the technological advancement in everyday life. This rapid change can be a source of uncertainty especially when one considers that software taught to Year 7 (11–12 years old) students today will often be outdated by the time they finish compulsory secondary education in Year 11 (16 years old). Perhaps more significantly, because of these issues teachers struggle to encourage creativity when teaching CAD/CAM within design and technology education. 3D solid modelling software is particularly difficult to use and be creative with in the early stages of learning the software. Furthermore Design and Technology teachers often struggle to keep up to date with rapidly changing software and frequently lack the confidence to teach it, which, in turn, affects their students' progress.

This research investigates the effects of teaching and learning CAD/CAM software and the impact this has on encouraging creativity in the classroom with Key Stage 3 students and their teachers. It suggests we require some rethinking concerning what we want students to know and be able to do and considers an alternative pedagogy which may help students to achieve more creative outcomes when using CAD. The research is undertaken through an intervention study within an action research framework. It outlines new methods and strategies to improve the confidence and creativity of students when using 3D modelling software and addresses the reality of day-to-day teaching pressures.

YOUR ACCEPTANCE

1 Student details	Your full name: Deborah Winn Personal identifier (PI): Y4810896 Affiliated Research Centre (ARC) (if applicable): Department: Design, Environment, Development and Materials Thesis title: CAD and Creativity at Key Stage 3: Towards a New Pedagogy
2 Authorisation statement	I confirm that I am willing for my thesis to be made available to readers by The Open University Library, and that it may be photocopied, subject to the discretion of the Librarian Signed: ......DSWinn...... Print name: Deborah Winn Date: 16/11/12 DD/MM/YY

3 British Library Authorisation (PhD and EdD candidates only)	The Open University has agreed that a copy of your thesis can be made available on loan to the British Library Thesis Service on a voluntary basis. Please indicate your preference below: ☒ I am willing for The Open University to loan the British Library a copy of my thesis OR ☐ I do not wish The Open University to loan the British Library a copy of my thesis

Declaration

This is to certify that:

This thesis comprises only my original work towards the PhD except where indicated, and due acknowledgement has been made in the text to all other material used. It is less than 100,000 words in length, inclusive of all footnotes, bibliographies and appendices.

Deborah Winn

January 2012

Glossary of terms

AAUW American Association of University Women

AQA (Assessment and Qualifications Alliance) English Key Stage 4 and 5 examining board

CAD Computer-aided design

CAM Computer-aided manufacturing

CSCL Computer-supported collaborative learning

DCMS Department for Culture, Media and Sport

DCSF Department for Children, Schools and Families

Design and technology A subject taught in schools which is the study and production of man-made products for people to use. It differs from other subjects in that it considers 'what if?' as well as 'what is?'

DfE Department for Education

Key Stage 3 Students from Year 7 to Year 9 (ages 11–13)

Key Stage 4 Students from Year 10 to Year 11 (ages 14–16)

OCR (Oxford, Cambridge and RSA Examinations) English Key Stage 4 and 5 examining board

Ofsted Government department that inspects and regulates schools

PLTS Personal learning and thinking skills

SEAL Social and emotional aspects of learning

3D SMCAD 3D solid modelling computer-aided design

Year 6 Students 10–11 years of age

Year 7 Students 11–12 years of age

Year 8 Students 12–13 years of age

Chapter 1 Introduction

1.1 The purpose of this thesis

Technology is finding a role in many traditional aspects of school life at primary and secondary level. Previously the development of very practical skills, such as working with resilient materials and acquiring skills and knowledge of tools and safe working practices, was achieved through pupils creating tangible products in the classroom.

In recent decades there has been a major shift in the Design and Technology curriculum away from manual techniques and towards digital processes and products, particularly in the secondary curriculum. This is partly due to increased health and safety regulations, which make practical projects more confined, and restrictive budgets but it is also due to changes in the needs of business and industry brought about by a shift in the way industry produces products. Students are now increasingly likely to make virtual products or use computer-aided design (CAD) and computer-aided manufacturing (CAM) instead of using manual techniques from a very young age. No longer confined to use in higher education (Musta'amal et al. 2009), CAD/CAM is not only commonplace it is also embedded into the English National Curriculum. The type of CAD software available in schools is wide-ranging and includes basic word processing, desktop publishing, image manipulation and vector-based 2D design software as well as more complicated 3D solid modelling programs which require specific commands to be followed to prevent the model failing.

This shift of emphasis has not been without problems. The equipment used to design and make, from basic computer operating systems to the more recent additions of laser cutters and stereo lithography machines, changes quickly and mirrors the technological advancement in everyday life. This rapid change can be a source of uncertainty, especially when one considers that systems taught to Year 7 (11–12 years old) students today will often be outdated by the time they finish compulsory secondary education in Year 11 (16 years old). Many students appear to find using this technology difficult or do not enjoy using it, especially if a student's model fails frequently or they are unable to create their own designs, and this hinders their Design and Technology education. Teachers often struggle to learn the programs themselves because teaching them is only a small part of the curriculum so a limited time is allowed for training. This often restricts the teacher's knowledge to the basic commands and so when trying to teach a class of students and problems occur the teacher is often unable to solve them. This is especially so if a length of time has passed between the teacher last using the program or the program has been updated and makes it frustrating for both students and teacher. Consequently teachers can sometimes avoid teaching the more difficult 3D solid modelling computer-aided design (3D SMCAD) software. The problem is further compounded when one considers the way CAD is often taught to students. The 'traditional' method of teaching involves the entire class following either a written set of instructions or a video clip in order to make identical products at the same pace in a 'lock-step' manner. Those students who pick up the commands quicker become bored waiting for the others to catch up, while those who experience problems are waiting for help, which in a large class can be several minutes. This restricts progress for both groups of students. This style of teaching is demotivating for both teacher and students and does not encourage either to take risks.

Despite the problems faced by teachers and students it is important that students are taught the more complex software. The use of new technologies in schools is increasing and not teaching the more complex programs in favour of the easier programs would limit the student options at this stage for a number of reasons. Ofsted (2004, p. 9) state that:

> The widespread use of specific ICT simulation software has freed pupils from this constraint (of spending time and resources making and testing products manually). They are able to quickly test out their design ideas on screen and the consequences of their decisions become immediately apparent. This encourages pupils to think as designers and it improves the pace of their learning and productivity.

The benefits of using complex CAD software can be summarised as follows:

1. CAD/CAM is used extensively in industry to make products and students need to have an awareness of how such products are made.
2. The more complex programs allow a greater number of additional features such as enhanced photo realism of their 3D product. Better-quality stereo lithography files are leading to higher-quality models being made with CAM and the ability to test the products with additional software, such as a virtual wind tunnel, or by using animation to see if the product will work.
3. Products can be transferred to other file types such as drawing files complete with dimensions, which is a reflection of how industry works.
4. 3D models allow students to visualise and rotate the product on-screen, which is a different experience for the student to that of drawing or physically making the product which can be both expensive and time-consuming.

Perhaps more significantly, because of these issues students and teachers struggle to embed creativity in Design and Technology education, which is surprising since creativity is considered by the Department for Education (DfE) as a vital skill to be developed in children in their various technology design-and-make assignments.

In response to providing for an unknown future, creativity has been seen by some experts as a possible way to help students not only to cope in an uncertain society but to thrive within it. Creativity has a key contribution to make to the economy if Britain is to remain competitive in world markets. As explored in Chapter 2 it is proposed by many experts that promoting creativity enables students to be confident to take risks, problem solve, form novel connections and innovate. This has been reflected within previous education initiatives such as 'Every Child Matters', 'SEAL (social and emotional aspects of learning)' and 'PLTS (personal learning and thinking skills)', which challenged teachers to consider each student's creative needs, abilities and potential. The intention of such initiatives was to provide a solid emotional base and develop self-esteem. This is especially relevant when considering the emotions involved in designing and the uncertainty created by the rapidly changing technologies involved in Design and Technology lessons.

One possible reason that students may struggle to be creative when using complex software such as 3D solid modelling programs in Design and Technology lessons is the way in which it is taught. As described above, the traditional 'command-centred' approach teaches students how to use the basic commands but fails to allow them to attempt their own individual ideas in the early stages of learning how to use the program. Observations demonstrate that often students do not gain an understanding of why they are doing what they are doing, for example putting a new sketch on a design, or how to recover from errors on their own. The command-centred method of teaching CAD appears to have limited results with Key Stage 3 students and an alternative method may be more appropriate, especially in encouraging students to be more creative in their use of CAD software. By investigating a different approach to teaching students which includes known and accepted ways of promoting creativity and addressing student concerns when using complex technology, it may be possible to improve their learning and allow them to be more creative.

The purpose of this thesis is therefore to evaluate two different approaches to teaching 3D SMCAD to Key Stage 3 students through an action research framework. By evaluating student progress and responding through intervention it is intended that the ultimate outcome would be to develop a teaching method which improves student learning and allows them to use CAD software in a more creative way.

1.2 Research aims

This research was undertaken with the following purposes in mind:

- To generate new knowledge that will suggest improved teaching and learning in the use of complex solid modelling CAD programs. Particularly the research aims to explore 'strategic knowledge'-based teaching in contrast to a more traditional 'command-centred' approach.
- To enhance students' creative abilities when using solid modelling CAD software.

1.3 Overview of the thesis

The thesis comprises an introduction, a literature review, an explanation of the methodology, a report of each study with an analysis of the results, and a conclusion. The conclusion summarises the results obtained, outlines the implications for current teaching practice and suggests possible further study. The thesis also reports on a pilot study used to illuminate and focus the research issues.

In **Chapter 2** current literature relating to the issues which surround learning CAD programs, creativity and emotion in education is examined to provide a framework for the programme of research. In the past, these topics in education have been largely considered separately and therefore it is necessary to begin by investigating each separately before considering how they interrelate. The evolving use of computers and digital technology in schools is explored in Section 2.2 to give an overview of how rapidly these technologies change, how teachers, students, parents and experts believe computers will change teaching and learning, and how computers may best be used to enhance learning. Section 2.3 provides a more focused view of computer use in Design and Technology lessons and aims to highlight the specific problems involved in teaching and learning CAD. Section 2.4 begins to explore creativity, initially by examining why creativity is seen by experts as an important issue in education. This is followed by a deeper exploration of some thorny questions such as 'What is creativity?' and 'Who decides work is "creative"?' From this understanding a definition is provided which is then used throughout this research. Section 2.5 aims to provide a more focused understanding by considering how teachers can teach for creativity, including creating an appropriate physical and emotional environment, and the role of evaluation in being creative before highlighting initiatives currently being used in secondary education. Section 2.6 further links these aspects by exploring current understanding of intelligence and learning, specifically in relation to emotion, creativity and learning 3D SMCAD systems. Section 2.7 summarises the research collected in this chapter and begins to formulate the research questions. A conceptual map of the literature review is presented in Figure 1.1.

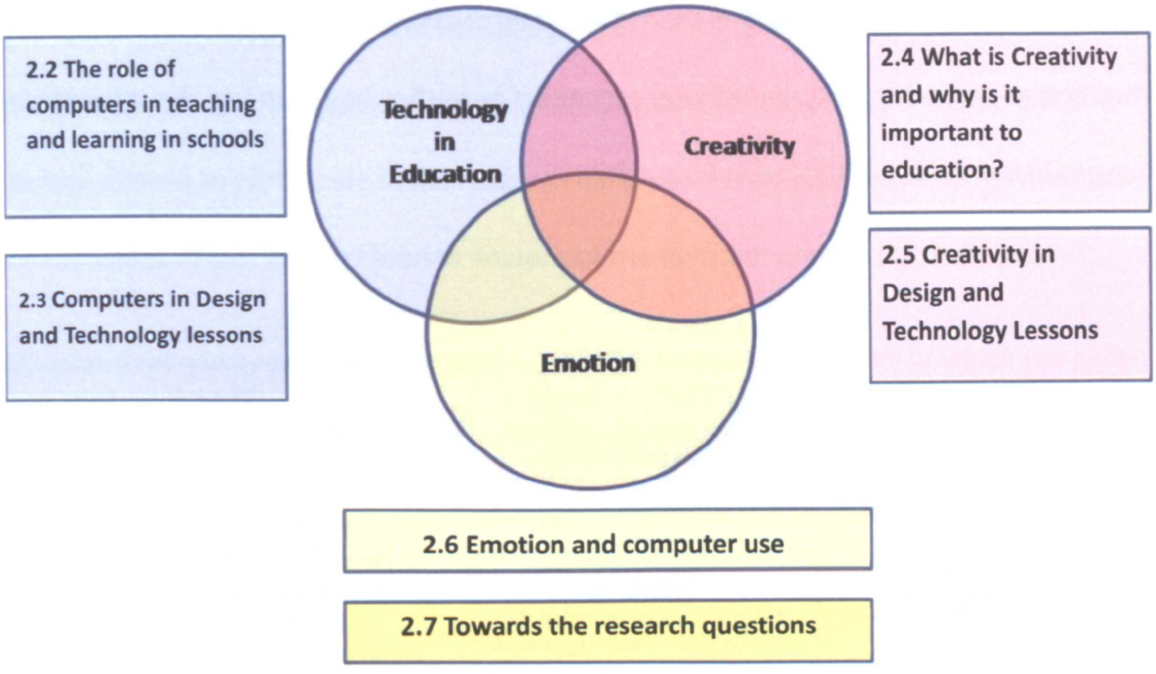


Figure 1.1 Conceptual map of the literature review

Chapter 3 reports on a pilot study that aims to examine which of the issues identified in Chapter 2 are most relevant to schoolchildren today. It is important to undertake a pilot study of this nature, as technology and attitudes towards technology change rapidly and some issues considered to be relevant at one point in time may no longer be relevant or may have been replaced by different issues. A further reason for completing a pilot study is the wide range of issues surrounding the areas of computer technology use in education, creativity and emotion. It would not be possible to research all of the issues in depth and the pilot study can act as a lens helping to identify which of them are most relevant to the research problems. While Chapter 4 provides a more in-depth review of the methodology and methods used throughout the remaining studies, Section 3.2 reports on the research methods used within this pilot study. This provides an understanding of which research methods have been used and why they are relevant to this study in particular. The study involves around 300 students who, through a controlled event, provide information on their attitudes and concerns before they begin to use the software, as well as data regarding their spatial and creative ability. Relevant data was then stored and compared against later responses once they began to use the software in lessons in the studies indicated in Figure 1.2.

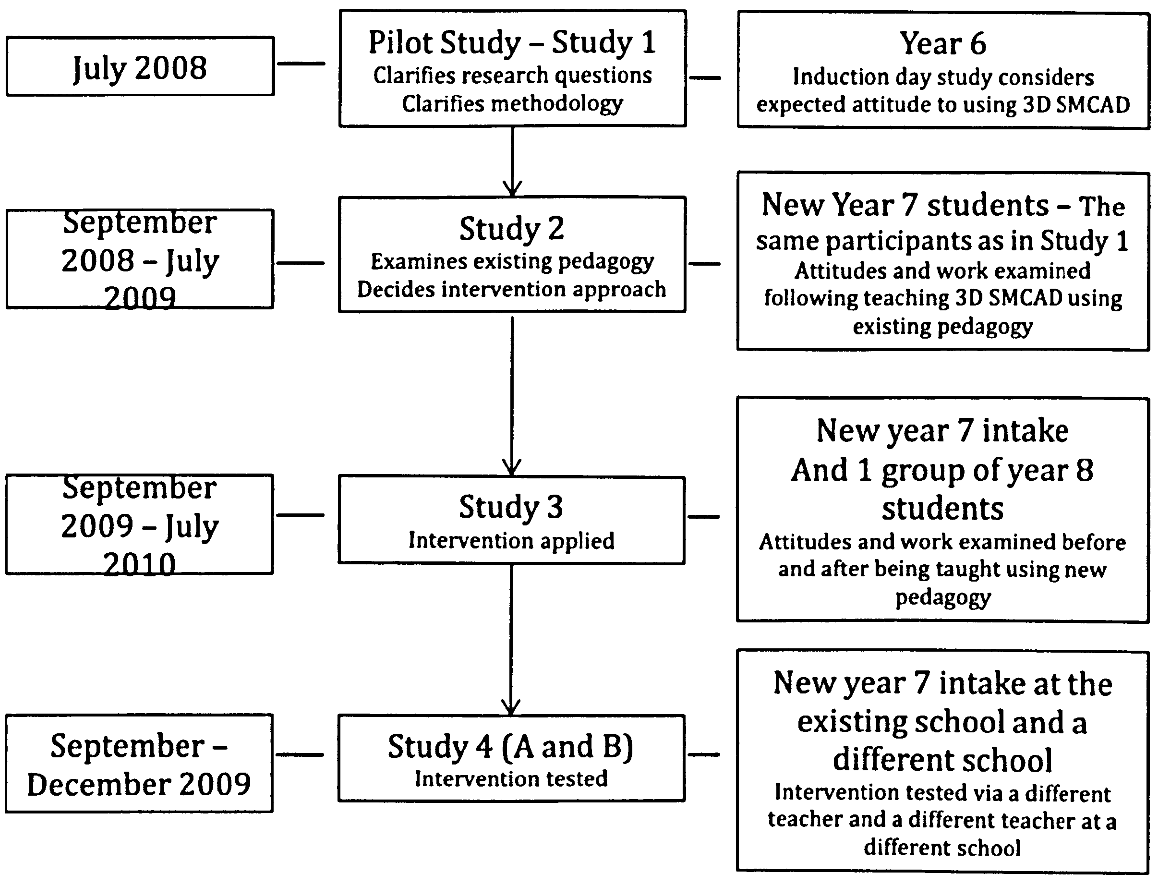


Figure 1.2 Timeline of research studies

Chapter 4 outlines the methodology used throughout the remaining studies that were undertaken. The purpose of this chapter is to examine the research methods chosen for the studies to ensure the reliability and validity of the data collected and the subsequent analysis of the findings. Section 4.2 considers which of the various research approaches would be most appropriate to the specific issues identified by the pilot study and to Key Stage 3 students learning computer-aided design in schools today. Section 4.3 explores the action research approach and considers its relevance to the studies that followed the pilot study. The chapter provides details of and reasons for the choice of venue and the sample chosen to participate in the research before exploring possible research methods, and provides details and a reasoned analysis of the methods chosen for these studies.

Chapter 5 follows several Year 7 groups (age 11) from the same school in which the pilot study had taken place through a course of study using the traditional approach to teaching CAD programs in schools. The chapter examines the students' attitudes and how these may change throughout the course. In particular the students' views are considered regarding how difficult they find the program to use compared to how difficult they expected it to be and how much they enjoyed actually using the program compared to how much they expected to enjoy using it. Perceived difficulty and enjoyment were chosen as foci for this study through analysis of the current literature regarding technology, creativity and emotion. These views are compared against the responses given during the pilot study to examine whether the issues they face when using the software change when they have actually used it compared to their expectations, thereby providing further illumination of the issues faced in the classroom by the students. The students' work was also examined to assess how competent they appear to be when using CAD and also how creative they are when they use it. Finally the chapter reports on the students' views collected via semi-structured interviews. The resulting data collected from this study was then used to create an intervention that may improve confidence and creativity when using CAD software.

Chapter 6, the intervention phase, follows six groups of Year 7 (age 11) students and one group of Year 8 (age 12) students from the next academic year through a course of study which uses a different technique developed using both the views of the students and known methods highlighted by the literature review to promote creativity. Only one group of Year 8 students were chosen for this study as this was the only group who had both experienced the traditional command-led teaching approach and had access to the teacher leading the study. At the end of the course the students' views relating to how hard they found the program to use compared to how hard they expected it to be and how much they enjoyed the program compared to how much they expected to enjoy using it are examined. The students' work is also assessed in the same way as in Chapter 5 for competency and creativity. The findings from this study are then compared to the results from the previous study in order to establish whether the intervention has been successful in promoting the creative and more confident use of CAD in Key Stage 3 pupils.

Chapter 7 reports on Study 4 which is split into two parts, 4A and 4B. Both parts of the study examine the reliability of the new teaching method but in Study 4A a different teacher delivers the intervention in the same school, while in Study 4B the intervention is delivered by a teacher in a different school. In both Study 4A and 4B the sample is made up of Year 7 groups. The teachers involved have less experience and confidence in teaching CAD programs to students and therefore it allows the additional factors of student perception of instructor knowledge and teacher view of the intervention to be examined within the study.

The first part of the chapter reports on the findings from Study 4A, where the teacher is the only variant. This allows for an alternative viewpoint on the intervention as other factors such as equipment and room setting remain the same.

The second part of this chapter reports on Study 4B, which further examines the reliability of the data by comparing the findings when the intervention is delivered by a teacher in a different school. This allows for the consideration that other schools may have students on roll with different attitudes to and experiences of using CAD software and equipment. Examining how the teacher and the students react to the intervention and the resulting work provides an additional viewpoint which can be compared to the original school in the study. As in the previous studies, in order to maintain consistency all other aspects relating to delivery of the intervention and the collection of data remained the same, where possible.

Chapter 8 reflects on the outcome of the research and the studies undertaken. It considers the contribution the research has made to computer-aided design education and suggests further research that could be beneficial.

Chapter 2 Literature review

2.1 Introduction

This chapter examines understanding of the three main areas that form the focus of this thesis through a review of published literature. The first part examines the rapid changes in technology that have occurred in secondary schools over four decades. It seeks to shed light on how computers have already changed teaching and learning. The general review is followed by a more focused examination of the way computers, and in particular CAD, have changed teaching and learning in the school subject of Design and Technology.

This is followed by an examination of creativity and an examination of influential factors in learning such as intelligence and emotion. The literature takes a broad view but seeks to leave the reader with a clear impression of the work to follow regarding creativity and emotion in the teaching and learning of 3D SMCAD systems.

2.2 The role of computers in teaching and learning in schools

2.2.1 The introduction of computers in the classroom

In the same way that technology has rapidly changed in the workplace and in our homes, the role of computers in schools has also advanced quickly, with many strong opinions as to their worth and how they would change education, including their effect on children.

The introduction of computers in British schools began relatively slowly, with the first computers being installed in the 1970s (Twining, 2002), and by the mid-1980s most secondary schools had a room with enough computers for a class. These computers were generally used in Information Technology (IT) lessons and taught word processing and programming tasks using MS DOS operating systems. By 1989 all students attending British schools had access to a computer, and a study by Livingstone and Bovill (1999) found that just over half of 6- to17-year-olds also had a computer at home by this date. By 2005, 75% of 9- to19-year-olds had access to the internet via a computer at home and 92% from computers at school (Livingstone and Bober, 2005). Several years on, the proportion of students with a computer at home is likely to be far higher.

Some radical theories accompanied the introduction of computers into schools. Illich (1971), for example, had a vision of a de-schooled society in which schools and teachers would simply wither away. Papert (1993) agreed, stating that he believed that computers would fundamentally change education – and ultimately make the school redundant. This view assumes that the student is motivated to learn and that computer technology could adapt to the student's progress and achievements rather than it being a tool in the same way as pencils or textbooks. This is not to say that technology does not have a valid place in distance learning opportunities, but without a driving force in the form of a teacher to respond to progress, mark work and praise achievements the process of learning would be very a very isolated experience whereby it would be difficult to know how to progress.

Others warned against the overuse of computer technology in education. Healy (1998) suggested that the fun element of computing can mislead children into regarding learning as a matter of instant reward. More recently Armstrong and Casement (2000) have argued that developing skills with the software emphasises speed and control at the expense of thoughtfulness and understanding. Further illustrating these concerns was a report entitled *Fools' Gold: A Critical Look at Computers in Childhood* (Cordes and Miller, 2000) produced by the Alliance for Childhood. This report documented profound objections to the use of computers in education and listed a number of potential problems and issues including physical hazards such as musculoskeletal injuries, visual strain and obesity; emotional and social hazards such as social isolation, emotional detachment and commercial exploitation; and moral hazards such as exposure to inappropriate material. The section on hazards is particularly pertinent to this research. Cordes and Miller warn that emphasising computers in childhood may cause a lack of creativity, stunted imaginations, impoverished language and literacy skills, plagiarism, and poor concentration. The concerns range from the obvious to the tenuous, that is, from potential repetitive strain injuries and the potential dangers of social networking sites to more vague concerns. In a review of the report Buckingham (2007) highlights that it assumes that children's use of the computer will replace other activities totally. Buckingham is also critical of the lack of a definition of key terms such as creativity and imagination and of the issues around their measurement. He argues that underlying these opinions:

> Is a broader suspicion ... of the apparent dehumanizing effects of technology: computers are deemed to promote forms of disembodied rationality and mechanistic, abstract thinking that are fundamentally at odds with human qualities such as emotion, imagination and creativity. They isolate students from their peers, parents and teachers, and hence prevent the development of fulfilling personal relationships, and deprive them of essential sensory and physical experiences that are vital for development.
>
> (Buckingham, 2007, p. 45)

It is possible that the overuse of computers may be detrimental to students and this literature highlights the need for teachers to carefully consider how computer use may benefit the students. The use of computers in education should seek to enhance and integrate with the planned learning experience rather than be an easy option or an 'add-on' to a lesson or because 'it's fun' for the student.

Others display a more positive opinion on the use of computers in education. In 1995 Bill Gates stated that 'computers will allow greater productivity and efficiency in education' and continued 'children naturally love computers ... kids and computers get along just great, because kids aren't invested in established ways of doing things'. This view was mirrored by Papert (1993) who suggested that computers had the potential to accommodate diverse learning styles and that technology often contributes to greater interaction among students themselves and between students and instructors. In the early years of the twenty-first century the climate was optimistic. Chen and Armstrong (2002) are also optimistic and offer the following positive outcomes and conditions for an IT-rich education:

- Greater effectiveness, in terms of time and cost savings, of the classroom teaching–learning processes.
- Greater motivation and satisfaction of students to learn with a variety of technologies. [According to Ofsted (2004) this can be seen in Design and Technology lessons, especially with regard to the boys.]
- Greater reach out to students who would otherwise not be able to study.
- Global access, communication and multiple interaction online and offline and self-management.
- New possibilities of monitoring students, individual progress, extent of interaction, study styles, etc. which are not possible without technology.

- Technology enhanced tasks for multidisciplinary studies, removal of barriers between subject and disciplines, which were otherwise adversely affecting education.
- Paradigm shift by way of evolving new roles of teachers and students.
- Students to explore for themselves as cognitive apprentices and teacher to be facilitators and change agents.

(Chen and Armstrong, 2002, p. 30)

The concerns raised in response to the rise in computer technology use in schools are valid, as are the positives. Used appropriately with sensitive regard to the individual, as with any set of tools available to the teacher, the use of technology in lessons will ensure that student learning is positive and enhanced and the negative effects are reduced.

2.2.2 Concerns regarding continued computer use in education

Regardless of the debate during recent decades, it was clear that the use of computers in education was here to stay. In the first decade of the twenty-first century technologies have driven an accelerating application of computers in the classroom. Indeed Cooper (2006) reports that computer software manufacturers have turned out hundreds of programs designed to assist teachers in delivering instruction in every discipline from art to zoology in an effort to make learning fun, but warn that more thought needs to be put into the design of these programs. To some extent this confirms some of the concerns raised previously with regard to computer use, namely that in an effort to make learning fun some of the subtleties in the game design and teaching with technology required to take advantage of the wide range of learning benefits possible were missed.

More than just in the changing design of the programs this expansion and the speed at which it takes place presents further issues that need to be considered and planned for in education. Skills learned now in Year 7 will be outdated by the time the child leaves school in Year 11, probably sooner. From the author's own experience, in the past six years some schools have implemented three new versions of CAD software along with three operating systems with a fourth introduced in 2011/12 (Windows 2000, Windows XP, Vista and Windows 7). Fisch and Mcleod (2007, pp. 24–6), made an interesting point with regard to this. Using web-based research the authors concluded that the amount of new technical information was doubling every two years and predicted that in 2010 new technical information would double every 72 hours! While this is not academic literature, and there is no evidence to suggest that the rate of increase in new technical information did occur at the alarming rate stated, there is no doubt that software and technology used by students is likely to have changed by the time a Year 7 student enters the workplace. This poses a problem previously noted by the author and succinctly put by Fisch and Mcleod (2007) who state that as teachers 'we are preparing students for jobs that don't exist yet, using technologies that haven't been invented yet, in order to solve problems we don't even know are problems yet'. In the opinion of the author, this echoes the reality of teaching Design and Technology today.

To ensure that the advantages of using computers in education are maximised it is important to consider here that using a computer in teaching is not a simple task and requires changes in educational practice to ensure that the tools are used in the most appropriate way (Sheingold and Hadley, 1990). This view was echoed in a teacher survey on the future of the classroom carried out by the Educational Foundation of the American Association of University Women (AAUW) carried out in 2000. One teacher was quoted as saying:

> Learning is no more about the computer than it is about a pencil. But, in saying that, I must qualify it isn't just a tool. The computer has profoundly changed the way we interact with information. So we must change the way we teach. Information is not learning, and the process of transforming information into knowledge/learning is what education is about. Teachers need to understand more about how learning takes place if they are to use technology to facilitate that learning. What do we want students to know and be able to do?
>
> (AAUW, 2000, p. 18)

The focus has clearly shifted from the technical aspects of the software to how we as teachers can best use it to enhance teaching and learning in our classrooms. While the type of computer use may differ in various teaching situations some elements remain the same; it is these aspects that are frequently the focus for research and discussion. Within a Design and Technology lesson, for example, the student may use a wide variety of software from generic software such as word processing or subject-specific interactive software which aids self-learning in the form of instruction then question and answer, both of which require little instruction, to other software which may be subject-specific, such as photo-manipulation and modelling software which require instruction. It is the common elements in these programs which are identified by Squires and McDougall (1994) in 'The Perspectives Interaction Paradigm'. Their framework considers that there are three people involved in the use of educational software, the teacher, the student and the designer (of the software), and focuses on the interaction between these people. It considers the interaction between the teacher and student while the software is being used, how students' learning can be improved while using the software and how the teacher uses the software to improve and extend their teaching. Research in this area is a clear indication that the benefits of using technology in lessons outweigh the negatives, although to establish an effective pedagogy when using CAD programs in schools the interaction between these three people needs to be carefully considered.

Twining (2002) also suggests the use of a computer practice framework to enhance planning the use of ICT in the classroom as well as exploring the impact that using ICT has had in practice. The framework considers primarily three aspects: quantity (i.e. the amount of computer use during lesson time), focus (i.e. the objectives supported by computer use) and mode (i.e. the impact of computer use in the curriculum).

Emotion is an important force in learning and it can affect how information is received and processed. This is especially evident in computer use. There is considerable research that centres on the 'technophobia' some students feel when considering using a computer, and this has opened new debates on gender differences in student performance. Evidence suggests that some students embrace ICT while others are apprehensive about their own abilities to develop technological skills. A concern noted by the author of this thesis during lessons and previously raised by Musta'amel et al. (2009) is that 'perceptions that users have of CAD systems and their expertise can significantly influence their performance' (p. 54). A further concern for students is one of image, as often students are concerned others will view them as the stereotypical 'computer geek' (Valentine and Holloway, 2001). Other emotional concerns involve the interaction between the student and the instructor, for example student perceptions of an instructor's knowledge. Research has shown that the more confident and able an instructor appears to be the more positive the attitudes of the students towards computers (Pektas and Erkip, 2006). This follows Banduras's theory (1997) that a positive role model increases the student's self-efficacy. This theory also identifies negative effects; Smith (1986) reports that when student confidence increased following exposure to computer classes the instructor's confidence went down.

As previously stated, prior research has shown that gender has an important role to play in the emotions and the way in which students use computers. Early studies reported that girls were more fearful of technology than boys and therefore spent less time using it (Collis, 1985; Culley, 1988). This was not a straight divide as girls were found to be more competent at programs like word processing and email and boys were more competent at programming and game playing (Turkle, 1984). Within these categories of boys and girls subcategories have been identified):

> *Computer-competent girls,* who use computers at home and school in a task oriented way including communication but rarely use the computer for leisure activities. *Techno boys*, who are highly computer literate and enjoy programming as well as hacking and game playing, often labelled by their peers as 'boffins' or 'geeks'. The *Lads*, who use computers for game playing and browsing on the internet trying to access restricted sites and the *Luddites*, who find computers stupid and boring and are reluctant to use them. These groups have different preferences when using the computers and need to be considered.
>
> (Valentine and Holloway 2001. P 68)

Further differences in the ways students approach computer activities were highlighted in *Tech-savvy: Educating Girls in the New Computer Age.* Written by the Educational Foundation of the AAUW in 2000, in response to growing evidence of a lack of interest and participation in computer activities by girls, the report considers ways in which the gender gap could be reduced. This gender gap was highlighted by a previous report written by the AAUW called *Gender Gaps* and was then summarised in *Tech-savvy:*

Educating girls in the new computer age. In its inquiries into gender issues in computers and education, the commission charged with writing the report found that:

> Girls are concerned about the passivity of their interactions with the computer as a 'tool'; they reject the violence, redundancy, and tedium of computer games; and they dislike narrowly and technically focused programming classes. They also often associate computers with solitary and isolated activities which they don't enjoy as much as social interaction. (AAUW p ix)

The AAUW report continues by stating that 'too often these concerns are dismissed as symptoms of anxiety or incompetence that will diminish once girls "catch up" with the technology' (AAUW p ix). The report suggests that rather than having a phobia of technology girls are providing a critique of computing culture which needs to be heard and responded to. The report quotes Siann (1997, p. 120) who wrote 'I can, but I don't want to', which suggests that women are being both pragmatic in relation to the rewards computing offers and making positive choices about wanting jobs that allow for the exercise of social skills and greater interpersonal contact. This view is shared by Clegg and Trayhurn (1999) who state that the question that should be asked is 'what is wrong with computing?' not 'what is wrong with women?' Some possible methods suggested by the report to try to reduce the gender gap include increasing the visibility of women who have taken the lead in designing and using computer technology and highlighting the human, social and cultural dimensions and applications of computers rather than the technological advances. Some of these suggestions have been addressed to some extent since the AAUW report was written and computer use has become more human and social. Social networking sites such as Facebook and Twitter have increased in popularity and more girl-friendly games such as role-play activities and interactive games that can be played with others have been released. As such, there is a growing debate as to whether the gender divide still exists (Livingstone and Bober, 2005), which is reflected in a wide range of research studies. Many believe that a divide does still exist but for a variety of reasons. Cooper (2006) believes that much of the gender divide is due to stereotyping from an early age which leads to a self-fulfilling prophecy. This view is shared by Carter (2010). Stoilescu and Egodawatte (2010) agree that a divide remains and report that the use of computers to complete a task rather than use manual techniques continues to be a source of anxiety for girls and women and that boys and men are generally more comfortable with using them. A more localised view specific to Design and Technology is offered by an Ofsted report from 2004 which noted a difference in male and female interaction with technology when it stated that overall the effective use of ICT in teaching brings several benefits to the development of pupils' Design and Technology capability, and that one of these benefits is increased self-esteem and motivation and this is especially seen in boys. In contrast to these studies, Uzun and Şengel (2009) report no significant attitude differences between genders, and a study by Khatoon and Mahmood (2011) states that during a mathematics task the females had an even more favourable attitude towards the computer-based work.

One possibility is that the divide exists but that it is task-related rather than linked to the technology in general. Livingstone and Bober (2005) report that there are differences in the types of website males and females prefer to visit, which presents different risks to each group. Carter (2010) believes that the divide still remains an issue because stereotyping exists, as computer software is often aimed at what boys like and as such, girls don't engage with it in the same way. Many of the games produced to assist in the classroom centre around standard arcade-type game themes such as war, sport or space. Girls prefer to use the computer as a learning tool rather than for play. Carbonaro et al.

(2010) suggest that game construction rather than play is a gender neutral activity and can teach higher order thinking skills. If a gender divide pertaining to a task exists, then activities which break down the known stereotype and promote confidence in those that need it, either males or females, are needed to promote the best learning experience when using complex CAD software. It is likely that this will require some careful consideration in terms of making any intervention appeal to both males and females.

2.2.3 Computer-supported collaborative learning

Computer-supported collaborative learning (CSCL) may aid computer learning especially when considering the gender issues that exist. Empirical research has shown that CSCL may facilitate deep learning and may provide motivational benefits (Lipponen et al., 2003). Webb et al. (1995) state that students can benefit from both giving help to and receiving help from their peers. The process of giving explanations may encourage explainers to clarify or reorganise material in new ways, recognise and fill in gaps in understanding, recognise and resolve inconsistencies, develop new perspectives, and construct more elaborate conceptualisations than they would when learning material by themselves. This was identified in studies in which students developed positive interdependence, shared resources and verbalised thoughts for learning to achieve joint solutions to a problem (Johnson and Johnson, 2003; Terwel, 2003). These aspects also feature in much of the research in developing creativity in students and will be discussed later. CSCL is certainly one method which may help support all students. Gender, ability or social advantage should not necessarily be seen as a problem but as a basis on which knowledge-sharing and therefore knowledge-building could perhaps be established.

There are some concerns, however, that in some cases students participate less in discussion (Guzdial and Turns, 2000) and CSCL does not always result in shared knowledge as not all students participate to the same extent (Lipponen et al., 2003). One factor which may prevent advancement of knowledge is that students often prefer to help by doing the task themselves rather than explaining or using questioning techniques in the way that a teacher would. When working together on problem-solving activities using computers boys will often assume the role of expert whereas girls tend to focus on the group process and communication (Volman and van Eck, 2001; Prinsen et al., 2007). Some studies found girls do better in single-sex groups whereas others do better in mixed sex groups, although in mixed sex groups the boys usually control the work being performed on the computer (Barbieri and Light, 1992; Underwood et al., 2008). Boys appear to find computers more attractive and feel more confident about using their computer skills (Prinsen et al., 2007). Two studies completed in 1999 and quoted in the AAUW (2000*)* found that all-female or majority-female groups of students cooperate substantially more on computer tasks than majority-male groups or mixed pairs. Regardless of group composition, females use a more inclusive language than males in discussing their work, and give constructive advice to boys more than the converse. With regard to working with complex CAD systems in a collaborative situation, the girls appear far more likely to work on the presentation side of the task than on realising their designs through CAD, which would often be completed by the boys. A study by Willoughby et al. (2009) suggests that collaboration in mixed sex groups works well with younger students but as the student gets older they become more concerned with personal 'image' and the girls lose confidence; therefore better progress is made in single-sex groups. They report that often mixed sex pairs also become more distracted from the task than in single-sex pairs as they get older. From observation by the author in class situations single-sex pairs suit most, although not all, students. Some mixed sex pairs work well and can provide an interesting mix in terms of confidence and approach to the task. It is likely that suitable pairings are individual and should be partially as a result of a response to these studies and partially as a result of sensitive direction from the class teacher in response to the individual's needs.

To obtain the best possible outcome from collaborative working it is important to involve all students in the process. Cohen (1994) proposes that periods when students are off-task, producing low levels of outcome or are experiencing interpersonal conflict are when the teacher is most likely to intervene. The type and quantity of teacher intervention can support problem-solving within both collaborative and individual learning situations. Meloth and Deering (1999) argue that high levels of intervention using questioning need not prevent the group's interdependence and discussion, as sometimes the group do not have enough information to complete the task. Meloth and Deering continue that often helpful comments from other students are made once the students understand where they are going wrong, therefore increasing group discussion. Webb et al. (1995), however, believe that further research is required and should focus on peer interaction and intervention required in group work when structured and unstructured tasks are undertaken by the students. Cohen (1994) identifies that in structured tasks that have a correct answer helping behaviour should focus on achievement whereas in ill-structured tasks with no defined outcome encouragement should focus on an exchange of ideas and strategies. When using CAD to develop creativity both structured and ill-structured tasks are evident, for example by following a command sequence the student will achieve a particular 3D model as in a structured task but to be creative, original work will need to be ill-defined by the teacher and therefore decided on by the group through discussion and cooperation. The task then becomes structured again when trying to model creative ideas using CAD where a clear outcome is required but where students may be unsure of how to achieve it.

Teacher involvement is also an important factor when using CSCL to develop creativity when using digital tools. Chiu (2004) believes that teachers can help students achieve a positive outcome when using CSCL by using questions to engage them; this has more success than just using statements or commands, although the intensity of questioning should vary. Using questions to direct students to solutions emphasises their responsibility over their own work, promoting interdependence within the group and reducing dependence on the teacher (Cohen, 1994, quoted in Chiu, 2004). Cohen also states that low levels of intervention will lead the group back to the task and promote further group discussion.

Considerate use of CSCL appears to be an appropriate method to minimise the possible negative effects of using computers in education highlighted earlier in this chapter as a de-schooled society with reduced communication skills and isolation. CSCL also seems to appeal to female students and may therefore reduce any differences in attitude to CAD use in lessons. Appropriate resources and teacher involvement would be vital in achieving a positive outcome, however.

2.3 Computer use in Design and Technology lessons

2.3.1 2D and 3D software

In addition to the generic concerns relating to computer use in schools, the introduction of computers into Design and Technology lessons has involved some very specific and complex software and hardware which has brought with it some unique issues concerning both teaching and learning.

From 1999 computer use in schools was extended and instead of remaining solely in the ICT domain all subjects have had to teach ICT (DfE, 1999) as part of the curriculum, including Design and Technology. This was followed in 2002 by the Key Stage 3 Strategy which included improving ICT capability (DfE, 2002). This saw a renewed focus on computer suites and specialist teaching in secondary education (Kennewell et al., 2003) but issues of teacher attitudes are still factors in the effective use of ICT across the curriculum (Williams et al., 1998).

Digital tools now feature more commonly in education. Many examination boards, such as Oxford, Cambridge and RSA Examinations (OCR) and the Assessment and Qualifications Alliance (AQA), offer the opportunity to submit coursework online and fully expect it to incorporate photos and photo diaries as evidence, which candidates will have taken with a digital camera and downloaded onto the computer. Their use has become embedded in the National Curriculum driven by a widely recognised need to provide students with information technology skills to meet employment needs. In the school in which most of these studies took place, using podcasts, mobile phones to take photos or record notes, and iPads is commonplace in a variety of lessons such as Science, Music, History, Media, ICT as well as Design and Technology. Searches of other schools' websites show that this use of new technologies is becoming commonplace. Some of the software used in lessons, even humble word processing, has facilitated highly creative work (Jorum et al., 1992). It seems that word processing can support average writers giving them a freedom to generate and delete ideas. However, some studies of very simple CAD software report no significant change in levels of creativity (Michael, 2001).

One of the specific digital tools now commonly used in Design and Technology lessons in schools is CAD/CAM, which was introduced into the National Curriculum in 2000. After 2000, CAD/CAM resources in schools quickly improved and in 2002 an Ofsted report on the effect of government initiatives in relation to ICT in schools revealed that 'overall ICT is more widely and better used in Design and Technology than in other subjects' (p. 4). The report continues:

> Computer aided design and manufacture is a major and influential development that has stimulated much successful work using ICT. By far the most effective factor in developing the use of ICT in design and technology is the provision of advanced 3D modelling software, often provided free of charge and linked to completion of specific in-service training.
>
> (Ofsted, 2004, p.4)

This scheme was run by the Department for Education and Skills and the Design and Technology Association. Almost two-thirds of the secondary schools in England have been involved in recent academic years.

Both the 2D and 3D software that have been made available to schools have some obvious differences regarding how difficult they are to use. 2D systems make use of simple geometry and less use of dimension, which can be easily changed in a similar way to changing font sizes in word processing programs. Drawing rules are less important, for example crossing lines, gaps and small stray lines do not necessarily cause the model to fail. *Techsoft* 2D design software is used in 4557 schools in England (personal communication, *Techsoft*, July 2012) in conjunction with either a laser cutter or a small 2D bench top CNC machine such as the Roland Modela. Both the software and the hardware in this instance are relatively easy to use and teachers and students are usually able to become proficient quite quickly.

The 3D systems used in schools are far more complex and are generally parametric modelling systems, which are feature-based. These are far more difficult to use than the 2D programs; for example, to create a solid shape the user needs to select 'features' such as extrude, loft, revolve and sweep, so for this to happen, students must initially recognise the names of the features and what they do. Once a basic sketch is created, it is transformed into the chosen feature to create a solid model which can be rotated so that all sides are visible and each surface can be worked on individually. The feature can use positive or negative space, which means that material can be added or taken away as needed. The model acts like an actual product in that it can be tested for weight, aerodynamics and whether it clashes when combined with other parts. These 3D systems are more reliant on accuracy to complete a successful model therefore it is important to get the dimensions correct in the early sketches if the model is not to fail. Modification of an object can take place once the sketch has been transformed into a solid. In addition to the dimensioning constraint, students also frequently struggle with the concept of having shapes on different workplanes or layers and with knowing that the shape must be whole and without errors for it to be successful.

An updated report by Ofsted (2004) to examine the effect of Government initiatives states that 'CAD/CAM has been a major development that has stimulated much successful work in D&T. However, teachers have to cover basic skills with the software before pupils are able to use it confidently and creatively' (p. 5). The issue of instructor ability is one that needs careful consideration. From discussions with many Design and Technology teachers few, if any, teach only CAD/CAM. Rather teachers need to have knowledge of a wide range of skills used in Design and Technology lessons, which includes CAD/CAM, and even then some only teach CAD/CAM for a few weeks in a year. This means that it is difficult for teachers to become 'experts' in the use of the programs. Time allowed for training is limited and sometimes the software has been updated before the teacher uses it again. From a teacher perspective the need for the model to be completely correct and not to fail, coupled with the limited time to learn and use the software can cause the teacher to lose confidence. This lack of confidence on their part may also affect the confidence of their students to use the software. The need for a high level of expertise to teach CAD and the difficulties faced to gain and maintain that expertise means that using CAD/CAM in some schools can be limited, which ultimately restricts the students' experiences. Primarily two companies have made low cost 3D solid modelling software available to schools and both of these require the student to understand command knowledge and have an ability to rotate and manipulate 3D solid components on monitor screens.

2.3.2 Spatial intelligence

Consideration of types of intelligence was popularised by McCarthy (1972), Sternberg (1985) and arguably and most notably Gardner (1993). This theory highlights that there are several types of intelligence and students can display higher levels of intelligence in one area than another. One type of intelligence identified in this theory and required when using CAD software is spatial intelligence, which requires particular consideration for this study due to the in-depth nature in which it is exhibited in 3D programs. Students do not have a tangible article which they can manipulate and rotate manually; tasks are completed mentally or on 2D screens, which may present problems.

Spatial awareness is an organised awareness of the objects in space around us and our body's position in this space. Gaughran (1996) extends this theory by recognising further categories within spatial intelligence and as with the multiple intelligence theory a person who excels in one area of spatial awareness may not excel in another. He refers to this as sub-factor theory and lists the subcategories as follows:

- Image holding and comparing – refers to the ability to remember and compare images in the mind.
- Planar rotation– refers to the ability to rotate a 3D object about an axis on a single plane.
- Orientation – refers to the ability of being able to visualise yourself (the spectator) rotating around the object.
- Kinetic imagery – refers to being able to rotate the object on any axis in the mind.
- Dynamic imagery – refers to the ability to manipulate the elements such as exploding the object, modifying and reassembling the object in the mind.

(Gaughran, 1996)

The use of digital technology, especially 3D SMCAD software, in the classroom offers the opportunity to both develop spatial awareness and methods and communicate spatial concepts necessary for understanding the visual information in children's minds (Hermer-Vazques et al., 2001).

The child needs to communicate the mental image of their idea to others and will need to convert 2D to 3D images and back again. For example, the child may form a few cognitive ideas as 3D images, which they will rotate between until the final idea is formed (image holding and comparing). To communicate this in a class situation, children are often asked to draw their idea. Initially with children this is usually completed in 2D form. The idea is then converted back to 3D as the child uses the modelling software. To view the whole product the child will need to rotate the object on the axis (orientation or kinetic imagery). Finally, as part of the design process, the child will need to imagine and implement modifications to their object following evaluation (dynamic imagery). Rynne and Gaughran (2007) believe that improving cognitive modelling will result in improved ability to extract and use procedural knowledge as well as command knowledge. This confirms that some students struggle to produce creative results using 3D solid modelling software based on their cognitive and spatial ability. This does not necessarily mean that the student will be unable to develop the skills necessary to produce creative results, just that strategies to encourage their learning need to be identified.

A further barrier to students' learning is that 3D solid modelling software involves several issues specific to the software used. Commands and new vocabulary must be learned in order to use the software; words such as *extrude*, *workplane*, *spline* and *helix*, which may seem obvious to an adult, need to be learned and understood by the child, in addition to being able to navigate and select the necessary features. Research into learning CAD in industry is relevant to the school-based programs used, as both use similar features and language. Most of this research compares command and procedural knowledge. Ivan Chester (2007) believes it is important to distinguish between *command knowledge*, which involves the knowledge of commands and the procedures to use the tools and *strategic knowledge*, which involves alternative methods by which a task can be achieved. Lang et al. (1991) argue that while CAD expertise is differentiated by strategic and not command knowledge, emphasis when teaching CAD has centred on command knowledge. They state 'students are so busy learning the commands that little time is available for acquiring other kinds of information such as procedural (strategic) knowledge' (Lang et al., 1991). This view is also shared by Bhavnani et al. (1993). This command knowledge, while important, does not help to develop creativity. The concern then becomes how we can teach command knowledge while fostering an environment and learning strategy that develops creativity.

Hodgson and Allsop (2003) identify some problems university students have when using complex CAD systems in secondary education. While most students find sketching of profiles and basic features relatively easy, visualising datum planes, using the menu manager and orientating/visualising the model is problematic for other students. Hodgson and Allsop's research specifically relates to the transfer of knowledge from *ProDesktop* to the newer version of *ProEngineer* now available to schools, and mirrors my personal observations in class in that it indicates some children may experience a problem when using CAD to design with, as it is necessary to be able to orientate and visualise the model to create it. Often students choose to design on paper and only use CAD to present their final ideas. Musta'amal et al. (2008) recognise this and identify two types of user when using more complex CAD systems, those who use CAD as a recording tool and those who use CAD as a designing tool. The recorders use CAD to present their final ideas whereas the designers use CAD to develop their ideas. Their research has demonstrated that all participants displayed creative behaviour while using CAD, but anticipating using CAD throughout designing made the likelihood of creative behaviours being displayed through design development work greater Musta'amal et el. (2009) conclude in a later article that CAD use can certainly be associated with developing creativity, and the activities it supports can be associated with creative behaviours. One question raised by this research is whether school-age children using 3D SMCAD would react in a similar way?

2.4 What is creativity and why is it important to education?

A second focus in Design and Technology lessons is the issue of creativity. This is an aspect first introduced to the Key Stage 3 curriculum in 2007 and introduced by the examination boards to the Key Stage 4 curriculum in September 2009. The questions raised from this change in the curriculum are: 'Why is it seen as important that school-age children are taught to be creative?' and furthermore 'How can you teach creativity?', and finally 'Is it possible to teach students to be creative with complex CAD software?'

The primary reason that emerged from a review of the literature for the introduction of creativity to the curriculum is that developing new skills such as creativity is necessary for students to be able to cope and thrive due to the sudden increase over the last 50–60 years of technological and economic changes, which are having a massive impact on the way we live our lives (Robinson, 2001).

New and often very specific skills and technological knowledge are necessary both in the home and in the workplace: for example, being able to work remotely and the increased use of information technology systems such as email, CAD and CAM, just-in-time (JIT) production systems and computer-based stock control. As stated in Section 2.2 these may be different in five or ten years and as such, new skills need to be learned and current skills and specific technological knowledge need to be continually updated to remain effective. Using new and constantly evolving technologies such as the ones mentioned involves a certain amount of risk-taking and uncertainty, which is a major cause of stress (Leitch, 2003). On a personal level developing creativity is seen as a method of preparing people for this uncertainty. Sir George Cox in the *Cox Review of Creativity in Business: Building on the UK's Strengths* (2005) extends this theory to a more global level and believes that developing creativity is necessary for the future and furthermore should begin in schools. The report also warns that significant changes must be made within the next five to ten years if the UK is to remain competitive within the world markets.

Robinson (2001) also believes it is essential to encourage creativity to give children the tools to cope and thrive in this rapidly changing world.

Marsh (2010, p. 4) agrees that creativity is an essential tool to allow students to prepare for the future and writes in *Childhood, Culture and Creativity: A Literature Review*:

> 'fostering creativity is fundamentally important because creativity brings with it the ability to question, make connections, innovate, problem-solve, communicate, collaborate and to reflect critically. These are all skills demanded by contemporary employers and will be vital for young people to play their part in a rapidly changing world.'

Students develop self-esteem and self-confidence because being creative allows them to have a sense of control over the choices they make while they take risks and solve problems. This strategy is even more powerful if failure is seen as part of the process to a solution and previously formed part of the Government's SEAL and PLTS strategies. PLTS and SEAL were in force in schools at the time the studies took place and the intentions involved in these initiatives are particularly relevant to attempting to encourage creativity when using CAD. These are discussed later in this thesis.

Best and Thomas (2007) combine these aspects and write that creativity is important on many levels both personal and for employment:

> Individuals – a human trait which defines the human species and provides a sense of completeness and purpose.
>
> Society – encourages diversity, connection and energy in human culture, through the entire range of endeavour, as well as human relationships.

Economy – provides the competitive edge in generating wealth, improving standards of living and arguably quality of life.

Environment – preserving and enhancing the natural and built environment, as well as seeking the balance when conflicts of interest arise.

Education – enabling individuals to find solutions, solve problems and develop the resourcefulness that will be required throughout their lives in a world of change.

The term creativity has provided the focus for a considerable body of published material. Definitions, techniques and applications of creativity have occupied researchers for several decades. However, there is much disagreement among researchers about what we mean by human creativity. To some extent this might be a consequence of the various backgrounds of the research community including psychology and other human sciences, art and design, and education. On the other hand our understandings are being challenged by new findings from research into the physiology of the brain and the processes of cognition.

Consideration and research into creativity is not new, although work in creativity has gained a recent popularity, the question of what is creative work and who decides it is creative has been posed for some time. Stein (1953) defines creativity as 'a process which results in a novel work that is accepted as tenable, useful or satisfying by a group at some point in time'. This suggests that a student's work could be viewed as creative when judged against the rest of the group, or the student's teachers believe the work to be original and appropriate to the design problem.

Later research considers types of creativity. Csikszentmihalyi (1996) believes that the word creativity covers too much ground, which causes confusion. In an attempt to dispel this confusion he separates the definition of creativity into three main types. The first is displayed by people who seem unusually bright or talented. Csikszentmihalyi believes this is not actual creativity but the person being particularly skilled in their area. The second type describes people who experience the world in original ways that only they know about. He refers to this as personal creativity but still does not see this as real creativity as it does not influence others. The third type, which Csikszentmihalyi defines as real creativity, is 'any act, idea, or product that changes an existing domain, or that transforms an existing domain into a new one' (1996); he refers to this kind of creativity as creativity with a capital 'C'. This is the type of exceptional creativity shown by the likes of Leonardo, Edison, Picasso or Einstein, individuals who have changed our culture in some important way. It should be noted here that this type of creativity is considered an inherent personality trait that cannot be nurtured or taught. Csikszentmihalyi (1996) goes on to state that while children may show talent they cannot be creative because true creativity involves changing the existing ways of doing things, which is impossible unless the old ways of doing or thinking have been mastered. Others have a more open view and believe not only that children are able to be creative but also that creativity can be nurtured (NACCCE, 1999; Cropley, 2001; Isaksen et al., 2001; Best and Thomas, 2007; Mclellan and Nicholl, 2008; Rutland and Barlex, 2008). Boden (2004) also identifies different types of creativity: historical creativity (H-creativity) and psychological creativity (P-creativity). H-creativity is similar to the creativity with a capital 'C' model identified by Csikszentmihalyi (1996) in that it is a valuable idea that no one has had before. P-creativity occurs when someone has an idea that they could not have had before but it is known to others. In this the creative process becomes important. If the idea is shown to have been developed from exploration and evaluation that the child has undertaken, the idea has to be personally creative as it has used information and links that are original to the child. Boden's 'P' model of creativity supports the theory that most people are capable of being creative in a variety of contexts.

Recent understanding of creativity with regard to children is more open. Kaufman (2002) extends the 'big "C' and 'little c' model of creativity to include a 'mini c' that is creativity inherent in the learning process. Cropley (2001) identifies that discussion on creativity has a common core of three elements: novelty, effectiveness and ethicality. Bill Lucas (2001) defines creativity as a state of mind in which all of our intelligences are working together. It involves seeing, thinking and innovating. It is the ability to combine knowledge and experiences to solve problems. Lucas's definition of creativity above has held over the intervening years and shares elements of a more recent definition of creativity outside of education. Cohen (2011) states that creativity involves the production of something new or rare yet appropriate to a problem that is valued and accepted in the world. When considering this statement in relation to children, the product would need to be new to the child, which reflects Boden's 'P' model of creativity (2004), and the world would need to be the group the child was a part of, as children wouldn't have had the wider experience of current practice as Csikszentmihalyi (1996) concluded.

All our Futures: Creativity, Culture and Education written by the National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) was commissioned by the DfE to feed into the QCA review of the National Curriculum. The report highlights the need to raise young people's morale, motivation and self-esteem and states that creativity is an essential tool in doing this and every child is capable of being creative given the right media. It defines creativity as an imaginative activity fashioned so as to produce outcomes that are both original and of value.

These findings would suggest that as teachers our goal is to consider creativity as a process involving exploration and evaluation and that the type of creativity we should be concerned with is personal creativity, which is certainly possible when teaching children. For Design and Technology teachers this is specific to the type of practical creativity unique to the subject involving the study of and making of man-made objects, as opposed to musical or artistic creativity. Through discussion with teachers of Design and Technology they assess creativity in a similar way to each other which is practical for the subject. To evaluate the creativity of a student's work, Design and Technology teachers consider how different the student's work is from any example shown and how they have developed their ideas with shapes and combinations of shapes or materials as well as whether the work solves the design problem and is appropriate.

2.5 Practical creativity in Design and Technology

Further to *why* we should teach creativity and a definition of creativity, is the consideration of *how* we can teach creativity. Seltzer and Bentley (1999, p. viii) state that:

> To thrive in our economy defined by the innovative application of knowledge, we must do more than absorb and feedback information. Learners and workers must draw on their experiences and apply what they have learned in new and creative ways. A central challenge for education is therefore to find ways of embedding learning in a range of meaning for contexts, where students can use their knowledge and skills creatively to make an impact on the world around them.

Joubert (research officer for the 1999 NACCCE report mentioned above) sees teaching creativity as: encouraging beliefs and attitudes, motivation and risk-taking; persistence; identifying across subjects; and fostering the experimental and experiential.

Research in the 1980s also considered how people could be more creative. De Bono (1985) hypothesised that people used limited approaches to the creative process which, in turn, limits the outcome. He suggests the use of six different approaches which he symbolises with six coloured hats that can be put on either actually or imaginatively. De Bono believes that by teaching this system, people could be more productive both individually and collaboratively and will enhance the thinking process by encouraging creative, parallel and lateral thinking, improving communication, speeding up decision making and avoiding debate.

Diakidoy and Kinari (1999) believe that the facilitation of creativity in the classroom will ultimately depend on the teacher's ability to identify creative potential in students, to recognise creative outcomes, to encourage personal attributes and cognitive processes that have been found to relate to creativity, and finally to structure the educational environment in a way which will render it more conducive to creativity. They continue by identifying two issues: the extent to which training prepares teachers to successfully undertake the task of identifying and facilitating creativity in the classroom, and teachers' theories and beliefs about creativity and the factors which have been found to influence it.

A further factor which commonly features in much of the literature regarding creativity refers to creating the correct environment to encourage risk-taking and develop links between current known facets of knowledge. Isaksen et al. (2001) recognise a nine-dimension model for establishing a working environment to encourage creativity:

1. Challenge and involvement.
2. Freedom.
3. Trust and openness.

4. Idea time.
5. Playfulness and humour.
6. Conflict.
7. Idea support.
8. Debate.
9. Risk-taking.

Hunter et al. (2007) add to this in a fourteen-point model to include a positive peer group, resources, autonomy and reward.

Best and Thomas (2007) believe that the climate in which an individual's most effective learning takes place is in the zone of overlap between the areas of physiology, psychology and teaching and learning strategies. The first factor, physiology, includes facets which allow the learner to feel comfortable with their physical environment. This includes a comfortable temperature, hydration, nutrition, good oxygen levels and being free of illness. The second, psychology, involves the learner being in an appropriate emotional state to learn. Best and Thomas characterise this as being 'intellectually challenged and motivated without being negatively stressed'. This factor includes stress, challenge, motivation, self-image, inspiration, support, justice, respect, contentment and alertness/attention span. The third involves the use of effective teaching and learning approaches which are successful in achieving the intended outcome.

A three-feature model developed to analyse creativity in an educational sense (Rutland and Barlex, 2008) may help to assess creativity and aids teachers to consider how we can teach for creativity. It consists of:

1. Domain-relevant features – a set of practices associated with an area of knowledge, providing the knowledge needed to complete the task.

2. Process-relevant features – influencing, controlling the direction and progress of the creative process; constructive intervention without controlling the task.
3. Social, environmental features – macro/micro environmental, social and cultural issues, providing the correct environment to encourage creative activity.

Several of the above features appear frequently in any discussion regarding creativity and therefore should be considered when attempting to nurture it, although they are not always features on their own and often interlink.

The nine-point model is considered further by McLellan and Nicholl (2008) in a study, which involved all nine factors but which concentrates on only the first two, challenge and involvement, and freedom. The study reported an inconsistency in teacher and student perception of the level of challenge and freedom that the students felt they had compared to the amount the teachers felt they gave in technology lessons. Students reported that 'they didn't see the point of the work they were doing' and 'the tasks they did were repetitive and boring', others argued that they all made the same thing. Repetitive tasks involving all students creating the same model mirrors the current method of teaching CAD in schools and certainly acts to demotivate teachers and pupils and suggests a problem faced by teachers when trying to develop creativity. Skills need to be taught in order for the pupils to be able to use them in their projects, but how do you do this while allowing freedom in their work? It is possible that given the freedom, a class of twenty-plus students may want to create twenty different projects requiring twenty different sets of resources and a wide variety of skills. As a teacher how do you facilitate this within your classroom while meeting the constraints of lesson objectives, department budgets and time (a standard fifty-minute lesson allows an average of two minutes per pupil if they all require different instruction)? This issue becomes no less important when considering CAD projects which depend on command knowledge being understood before it can be used effectively. A further consideration is the possibility of failure; allowing students the freedom to make something that isn't going to work may arguably affect their confidence and desire to try again and does not fit within the current need for accountability in education. This is especially prominent in teenage children when emotional factors such as peer group pressure become involved. This is supported by studies showing that originality becomes more restricted as they move through secondary schooling (Sternberg and Grigorenko, 1997; Rutland and Barlex, 2008,). One popular publication, *Accelerated Learning in the Classroom* (Smith, 2007) outlines a connection with self-esteem, environment, learning and creativity. Smith believes that by creating a relaxed but challenging environment, fostering the students' self-esteem and catering to all learning styles (kinaesthetic, visual and auditory) students can be aided to both learn effectively and be creative.

A further aspect considered to be important in the creative process is the concept of incubation and evaluation of ideas. This is identified in the bed, bath and bus thinking of Margret Boden (2004) who considers that when the unconscious mind is allowed to wander it will make unusual links that conscious thought is unable to. Evaluation, including self-evaluation and redevelopment of these ideas, are then essential parts of being creative and form a solid foundation for the design process that aids creativity. Cropley (2001) believes that promoting self-evaluation helps the student learn more independently. An alternative viewpoint following a study by Szymanski and Harkins (1992) indicated that self-evaluation could harm creativity as the students tended to judge themselves more harshly. Amabile (1996) believes the method of evaluation influences this, as intrinsic motivation involves the person's own desire to complete the task and improve. Self-evaluation would be beneficial to this person in terms of creativity because they would want to improve as a personal experience. Extrinsic motivation involves the use of reward or competition to encourage the person to improve their work. Amabile suggests that to motivate students teachers should help them to identify where their interests and skills overlap to provide the optimum environment to develop creative work habits. Certainly provision should be made in lesson planning to allow time for self and peer-evaluation and students should be encouraged to use this reflection to influence their work.

An initiative that had previously been put in place to promote creativity in schools was Creative Partnerships, which was the Government's flagship creativity programme for schools and young people, managed by Arts Council England and funded by the DCSF and DCMS. It was founded in 2002 and although it was closed in October 2011 was relevant when the studies reported in this thesis took place. It aimed to develop:

- the creativity of young people, raising their aspirations and achievements
- the skills of teachers and their ability to work with creative practitioners
- schools approaches to culture, creativity and partnership working; and the skills, capacity and sustainability of the creative industries.

A more direct approach involved PLTS lessons to 'enable young people to enter work and adult life as confident and capable individuals' (QCA, 2008). The intention was to teach the lessons in addition to the current curriculum; however, in 2012 PLTS and SEAL initiatives no longer form part of Government policy. Both of these initiatives aimed to encourage aspects of creativity that are relevant to this study and as they were in force at the time the studies took place it is worth considering them in this thesis. The framework for these lessons comprised five groups of skills which aimed to develop the students as:

- independent enquirers

- reflective learners
- team workers
- self-managers
- creative thinkers.

The last of these is intended to develop a range of pupil skills including being able to generate ideas and explore possibilities, ask questions to extend their thinking, connect their own and others' ideas and experiences in inventive ways, question their own and others' assumptions, try out alternatives or new solutions and follow ideas through and finally be able to adapt ideas as circumstances change.

While each group is distinctive and coherent they are also interconnected.

Specifically in Design and Technology the expectation is that pupils are taught to 'combine practical and technological skills with creative thinking to design and make products and systems that meet human needs. They learn to use current technologies and consider the impact of future technological developments. They learn to think creatively and intervene to improve the quality of life, solving problems as individuals and members of a team.' (DfE, 2007, p51)

The lessons accompanied a change in the National Curriculum for Design and Technology introduced in September 2007, which added provision for creativity, as follows:

1.3 creativity

A Making links between principles of good design, existing solutions and technological knowledge to develop innovative products and processes.

B Reinterpreting and applying learning in new design contexts and communicating ideas in new and unexpected ways.

C Exploring and experimenting with ideas, materials, technologies and techniques.

(DfE, 2007 p53)

Some of the major exam boards such as OCR have also included creativity in their coursework specification, which was introduced to students in September 2009.

When in place Creative Partnerships, SEAL and PLTS did much to publicise the need to promote creativity in the classroom and moves by the exam boards are certainly good steps in the right direction but the steps taken still do not allow for the aspect of play or for the pupil to take risks without fear of criticism or failure across a range of skills.

Banaji et al. succinctly describe the difficulties in trying to balance creative practice in the classroom while meeting Government criteria in the *Rhetorics of Creativity* report written for the Creativity, Culture and Education organisation:

> The examples of 'creative teaching' given exemplify the tightrope that many educators have to walk between institutional constraints and the fragility of their constructed 'creative' environment. However, at times the tension also appears to lead to contradiction or even paradox: risk-taking is to be encouraged but it is also to be kept within easily controllable bounds; furthermore, time is required for playful engagement with ideas and materials, but this time has stringent external parameters in terms of the school day.
>
> (Banaji et al., 2010, p. 64)

While acknowledging its journalistic nature, the following article reflects the opinion of a seasoned teacher and highlights the difficulties faced when trying to combine creativity with targets in a real-world situation.

> I recognise that the Government is serious about raising standards, and to do so it probably realises the need to encourage creativity, calculated risk-taking, diversity and innovation. But the success of this policy will partly depend on the Government curbing its unreasonable, almost paranoid obsession with targets and the measurement of performance.
>
> (Robinson, 2007)

2.6 Emotion and computer use

When using complex systems such as CAD/CAM to design, emotions, both positive and negative, feature in the act of using the technology and also in designing and in being creative. Not all students embrace technology and complex programs such as the type used in 3D computer-aided modelling can create emotions such as fear or frustration, which could reduce motivation and creativity. Those that experience positive emotions can feel joy and pride in their accomplishments and may be more open to attempting difficult tasks. Musta'amal et al. (2009, p. 54) write that the perceptions that users have of CAD systems and their expertise can significantly influence their performance.

Heider's attribution theory (1958) considers that a child's attitude to the task will make a difference to how motivated they are in the task, which may also have an effect on the student's emotions. For example, the child with good self-esteem who considers themselves to be a poor runner may think 'I am not very good at running' and therefore not try very hard because they believe they will never improve. On the other hand they could evaluate why they do not consider themselves to be a good runner (poor training, bad diet, overweight) and work to improve their performance. This often appears to be evident in classes where young students believe they are 'no good with computers' and so do not attempt the task, thereby enforcing the student's belief that they are no good with computers. Others will try to establish how to improve and attempt the task regardless of their belief in their ability at that time.

Building on this theory Bandura (2001) considers that the person's perception of whether they can achieve their goal is not always linked to self-esteem. For example, a person with good self-esteem may consider themselves to be a poor runner and therefore have a poor self-efficacy regarding that task only. Bandura (2001) believes there are four factors which affect self-efficacy:

> Experience – successfully reaching small goals will increase the belief that they can complete the task, continual failure will reduce this.
>
> Modelling – seeing someone of a similar ability succeed will increase self-efficacy, seeing failure will reduce it.
>
> Social persuasions – encouragement or discouragement can increase or decrease a persons' self-efficacy.
>
> Physiological factors – a person's perception of their own stress reaction can be detrimental e.g. a person who is showing signs of low self-efficacy may view natural stress reactions such as shaking as reinforcement of their lack of ability.

What appears to be important within these theories when learning complex systems is whether the student wants to improve or whether they are content at their current ability level, and has less to do with ability or self-esteem. By breaking down tasks into small achievable goals it is more likely that the student will want to attempt tasks, have increased motivation and experience positive emotions such as enjoying the outcome.

Being creative is much more reliant on the student's self-esteem. As previously stated creativity requires a safe environment where ideas are encouraged; as the process is more important than the outcome and may not work out as the student expects, the student will need to take risks. Consider the emotions involved with the uncertainty and risk-taking necessary for designing and perhaps then displaying your creative achievement, which may or may not be considered appropriate by the criteria of others. This can be especially concerning as a teenager.

David Spendlove (2007) separates the emotions involved with being creative into three domains:

Emotion and creativity: Person domain. This area is concerned with risk, not only from the student's point of view, which has been discussed earlier in this document, but also from the teacher's point of view. This is also considered by Kimbell (2000) who argues that the pressures felt by teachers and students due to examinations and league tables stifles the ability to be creative and to allow creativity. Jon Parker also shares this view. Parker (2002) states that 'GCSE coursework assessment procedures discourage teachers (and presumably students) from breaking the mould' and he urges that we should be encouraging those who 'show real flair and imagination'. Kress (2000) argues for a more open curriculum where risk and uncertainty are welcomed rather than to reproduce existing practice.

Quite simply, by removing the need for the student to achieve a particular outcome to be seen as successful, but instead rewarding process, the student is more likely to experiment and try something that may not work, something that the teacher is more likely to encourage. Current practice when teaching CAD is the opposite of this and requires the student to produce an exact copy of a given product, thereby removing the risk and uncertainty but also stifling creativity. It would be far better to reward creative ideas and give students the emotional tools to cope with and even enjoy the risk and uncertainty, and allow teachers the freedom to let students experiment with their ideas.

Emotion and learning: Process domain. This involves the emotional climate of the learner and the context of emotional engagement within the learning process in Design and Technology. Ahn (2005) suggests that teachers can assist, to some level, to promote confidence and security by acting as a role model and by using positive and negative emotions constructively and modelling how to regulate them.

Again, by rewarding process rather than outcome the student will associate positive emotions with learning and trying out new ideas.

Emotion and outpoint: Product domain. This area involves the emotions regarding the product itself. It encompasses not only the feelings involved in making and using the product, but also the environmental, social and physical impact of their products. At Key Stage 3, when learning complex CAD systems emphasis is more likely to be on learning command sequences rather than on making a physical product; therefore this research focuses on Spendlove's first two domains outlined above.

Positive emotions such as joy, contentment, satisfaction, anticipated pride and challenge temporarily create a broader mind-set and prompt individuals to expand the self, share information with others and push themselves to the limits. Bowkett (2005) states that creativity incorporates playfulness, curiosity, sensitivity, self-awareness and independence, which are all positive aspects of the learning process. Spendlove (2007), however, warns that research has shown that negative emotions such as anxiety, fear and irritation hinder learning. Developing creativity in education can help children to experience and learn to deal with both positive and negative emotions and to establish good patterns of cognitive behaviour. The concept of teaching students to deal with emotion in an acceptable manner is now often referred to as emotional literacy and in conjunction with creativity is a very current theme in education.

The *Every Child Matters* Green Paper (DfE, 2003) intended as one of its aims to promote emotional well-being for all, including developing emotional literacy with regard to children and technology. This included trying to create an environment where risk-taking is encouraged and failure is seen as part of the process. As part of this process the 'social and emotional aspects of learning' (SEAL) resource was introduced into primary schools and into secondary schools in September 2008. SEAL intended to promote five aspects of learning with the aim of overcoming potential barriers to children learning by providing them with tools to be able to manage their feelings and social relationships better. The areas covered were: self-awareness, managing feelings, empathy, motivation and social skills. Following on from this the PLTS, outlined earlier in this thesis, also strongly linked emotional aspects of learning and creativity and aimed to improve the student skills in these areas. Although SEAL and PLTS are no longer features of Government policy overtly, it seems these are still important aspects in education for all students.

In order to improve the ability of a student to use complex CAD systems it appears that the student must expect to experience positive emotions such as enjoyment when learning the software in order to be motivated to learn it. This can be achieved by developing small achievable tasks that can be rewarded and praised; however, to foster creativity the student must be rewarded for the process rather than the outcome so as to provide a safe environment where the student is willing to take risks and experiment with ideas without fear of failure. While aspects such as creating positive emotions during the task are the same for both motivating the student and developing creativity, a focus on providing achievable tasks appears to be in conflict. An environment which fosters all of the aspects discussed would need to be provided to improve the student's ability to be creative when using complex CAD systems.

2.7 Summary

The use of computer technology in schools is advancing and is likely to continue to advance as new technologies become available. In 2002 an Ofsted report (HMI 701, p. 4) stated that Design and Technology uses computer technology more than any other subject outside of specific ICT curriculum lessons. Schools now commonly exploit the wide range of computer-based software and equipment used in Design and Technology lessons, from 2D and 3D design programs, image manipulation software and CAD equipment to virtual testing programs, as a specialist set of the software and equipment, for example data-logging, word processing, spreadsheets, databases and podcasts, used in other lessons.

Although there are many advantages to using computers in education, such as more personalised learning and the ability to accommodate individual and diverse learning styles, its introduction has not been without problems. Some of the concerns highlighted include a lack of creativity, poor communication skills, isolation and a desire for instant reward. Some female students appear to be more affected by the negative aspects of working with computers and require strategies to appeal to their learning preferences.

Teachers need to understand more about the learning that takes place when they are using technology and develop pedagogy to suit this media. Primarily this will involve consideration of what we want students to know and be able to do and also the interaction between the students and between the students and the teacher. Considering the complexity of some of the software used in Design and Technology lessons student perceptions of instructor knowledge and instructor perceptions of student knowledge may also be a factor in achieving a successful lesson using computers.

Computer-supported collaborative learning (CSCL) appears to be one method that, if used in conjunction with effective questioning, can alleviate many of the negative issues raised in the research. It is possible that through this method students may develop positive interdependence and verbalised thoughts leading to achieving joint solutions to a problem. CSCL also seems to appeal to female students and may go some way to changing the 'I can, but I don't want to' attitude of female students reported by the AAUW. Careful planning and questioning would be necessary to prevent an inequality in the amount of work and interaction each student accomplishes.

One program used increasingly in Design and Technology lessons is 3D solid modelling software. These programs are especially complex to use and rely on a high level of precision to prevent students' models from failing. Currently, when teaching this program the emphasis is centred on teaching command knowledge when expertise is differentiated by strategic knowledge. Students must still understand specific vocabulary and the necessary commands but a suitable method has not yet been established for secondary school students to teach command and strategic knowledge. Considering software changes frequently and may be outdated soon after the student learns it, a teaching method focused on what we actually want the student to be able to do would be more appropriate. A further factor which may prevent effective 3D solid modelling is varying the spatial ability in students; therefore including methods to improve this in lessons may also be beneficial.

A second focus in Design and Technology lessons currently is the issue of creativity, which can be defined as 'an imaginative activity fashioned so as to produce outcomes that are both original and of value', (NACCCE, 1999). Teaching creativity is seen as essential by experts because as teachers 'we are preparing students for jobs that don't exist yet, using technologies that haven't been invented yet, in order to solve problems we don't even know are problems yet' (Fisch and Mcleod, 2007).

Creative activity is believed to help students to cope and thrive in a rapidly changing society as it encourages self-esteem, and allows for risk-taking, adaptability and problem-solving techniques.

Providing the correct environment is essential in promoting creative behaviour. A nine-dimension model is recognised as follows:

1. Challenge and involvement.
2. Freedom.
3. Trust and openness.
4. Idea time.
5. Playfulness and humour.
6. Conflict.
7. Idea support.
8. Debate.
9. Risk-taking.

Current methods of teaching 3D solid modelling software do not allow students to be creative in the early stages of learning the program, as its complexity often provides too much of a challenge and does not allow students the freedom to produce their own designs. In order to improve students' learning of complex CAD systems and allow them to use the software more creatively a different method of teaching it must be established that considers all of the factors discussed in this chapter.

2.8 Towards the research question

A review of current literature highlights that as technology and students' attitudes to using it change rapidly and current research focuses on older students (age 18-plus) little is known about younger students' (age 11–17) current attitudes when using CAD. This poses an important question pivotal to this research. What are Key Stage 3 students' perceptions of using CAD in the classroom and furthermore do these perceptions influence their learning? In particular, as positive emotions such as enjoyment of the task have been shown to alter pupils' motivation in the task, does the students' expected enjoyment of the task change their perception of difficulty or challenge regarding the task?

The importance of challenge in a task is identified in the literature when teaching for creativity, which is also highlighted as essential in students' education for a healthy emotional and economic climate in the immediate future. Again much is changing in the curriculum to address this need and students' current ability to be creative must be assessed in order to gain an understanding of how much of an issue creativity is involving Key Stage 3 students today. More importantly, are Key Stage 3 students currently able to be creative when using CAD?

Not only do attitudes to using technology change but the literature suggests that the increased use of technology in the classroom should also provoke a change in the way we use it to aid learning. Current practice when teaching CAD does not follow this change in that most teaching uses a follow-my-leader approach whereby students all make the same thing with a focus on command knowledge – we are not yet asking 'what do we want students to know and be able to do?' Once examined, an alternative pedagogy is likely to be more appropriate and is identified through this research. One method reported in the literature as successful when teaching using a computer is computer-supported collaborative learning (CSCL). It is prudent to consider this when developing an alternative teaching method.

While the literature review has provided a significant quantity of knowledge and information it has also highlighted a considerable amount of questions that are as yet unanswered. In particular the following questions have been raised by the literature review:

Does the student's perception of their own ability and ease of use of the program change their ability and attitude to using the program?

How hard the student views a program to use may affect their ability to use the software for several reasons. Emotional aspects of learning and risk-taking have been shown in the literature to be an issue with regard to computer use, especially in school-age children. If the student views a program as easy to use does this affect the outcome of the task or attitude to using it either positively or negatively? A further concern is if the child believes the program to be easy to use but then struggles to use it does this affect how much they enjoy using it or the likelihood of them using it again? Alternatively, if the student believes the program will be difficult to use do they believe they will enjoy the challenge? Challenge without overwhelming the student has been shown to be an important factor in developing creativity in students.

Does the amount of computer use including access to computers outside of school affect ability and attitude to using 3D SMCAD programs?

Attitude to and the amount of computer use has been shown in the literature review to vary greatly among schoolchildren. How much does the attitude to and the amount of computer use affect their ability to complete a creative model using CAD software?

Do students expect to enjoy using the software more if a product is made at the end?

Creating a 3D model of a class of student designs in school can be costly and time-consuming. To what extent does the absence of a tangible product affect the student's enjoyment and confidence when using CAD software?

Does spatial ability affect expected enjoyment or difficulty when using CAD software?

CAD use involves a large amount of spatial manipulation. To what extent does the student's spatial ability affect both expected enjoyment and difficulty when using CAD software?

Can students be creative using traditional and computer-based techniques and does perception of difficulty and enjoyment affect the creativity of the final outcome?

It is possible that a student may display more creativity in one media than in another. How does the creativity of the student's designs on paper compare to their CAD model? Does the student's perception of the difficulty and enjoyment when using the program affect the creative outcome of the designs produced?

Historically gender has affected attitudes to computer use. Do some students respond better to different teaching methods such as CSCL?

Gender and computer use has prompted a wide range of research and is certainly worthy of note. To what extent do male and female students' attitudes to CAD use vary? Does varying attitudes result in a difference in the way each gender approaches using CAD? Finally does collaborative working aid either gender in learning to use CAD creatively?

In order to ensure that subsequent studies are more focused on the relevant issues this considerable body of questions needed to be investigated to allow the final research questions to be more precise. To achieve this aim the following research questions emerging from the literature review are addressed by a pilot study:

1. Which of the potential issues that emerged from the research gathered in the literature review affected school-age children most significantly when using CAD?
2. What are Key Stage 3 students' perceptions of using CAD in the classroom?
3. Do students believe that they would be able to be creative in the early stages of learning 3D SMCAD?

Chapter 3 reports on a broad-based pilot study that includes all of the aspects and questions identified in this chapter, providing a more focused approach to the following research and defining more precise research questions and aims.

Chapter 3 Study 1: Pilot study

3.1 Introduction

The previous chapter explored three phenomena that can be seen to exert a significant influence on learning and teaching in Design and Technology today. The first of these concerned the widespread use of ICT in the classroom plus its rapid development. For the purposes of this research the study has focused on CAD in schools. The second phenomenon concerned the learning styles and strategies used in schools. It is linked to the first through the development of skills in using CAD. The third phenomenon was the parallel need to develop creativity in schoolchildren. Chapter 2 began an evaluation of methods that could be used to undertake research that embraced these three phenomena. Some valuable prior research has been uncovered but the vast majority of this is limited to studies of university-age students and adults rather than school-age students and largely makes reference to creativity when using complex CAD software. There is a vital need for studies of school-age pupils, particularly at Key Stages 3 and 4. The literature review also identified issues around gender, spatial awareness and amount of computer use. The difficulty of exploring these issues is compounded by emotional factors inherent in this age group and the difficulty of uncovering attitudinal factors with pupils who may not be skilled at expressing themselves. Therefore, while creativity and CAD is a highly relevant topic for investigation the methods for such an investigation and precise research questions are not at all clear. What is needed is some 'research before the research', and hence the use of a pilot study.

To investigate which of the issues highlighted by the literature review relate specifically to Key Stage 3 students in education today, and to their learning of 3D SMCAD programs, it would be prudent to undertake a pilot study as the concerns raised in this research cover a very wide variety of issues which would be difficult to study in-depth. To gain a more thorough understanding of the most appropriate issues to focus any research an exploratory study would establish which of the concerns raised are the most relevant to schoolchildren using CAD today. This study included all of the relevant aspects identified as potential problems by the literature review and from the results of this study and from Study 2, an intervention was developed and delivered that targets areas which prevent the creative use of 3D SMCAD more appropriately.

This chapter reports on a pilot study which aimed to examine whether any potential issues, including emotional concerns, pre-exist when teaching Key Stage 3 students CAD and in addition whether children felt that they were able to be creative when using CAD. In particular the study aimed to answer the following questions;

1. Which of the potential issues that emerged from the research gathered in the literature review affected school age children most significantly when using CAD?
2. What are Key Stage 3 students' perceptions of using CAD in the classroom?
3. Do students believe that they would be able to be creative in the early stages of learning 3D SMCAD?

This programme of study aims to use findings from the literature review to design some relevant studies that illuminate how we might improve the teaching and learning of CAD in today's classrooms. A pilot study is seen as a key means of testing out some early ideas for research before investing time and resources in more detailed and focused investigations.

3.2 Research methods

In order to fully understand the findings of this pilot study a detailed report of the research methods used are included in this chapter.

3.2.1 Pilot study sample

To examine the issues surrounding CAD use in schools a reasonably large sample was needed to gain a variety of opinions and data as well as the inclusion of students from a wide range of ethnic and social backgrounds. A small sample would not provide enough variety of results to establish which potential problems in learning CAD need to be examined further. For example, one child out of ten students may find lack of spatial ability when learning CAD hinders his or her progress leading to assumptions that 10% of students also find lack of spatial ability an issue. If this same student were included in a sample of 300, however, and was the only student to find spatial ability a problem, then it may be that spatial ability would be less of a concern in terms of this research. A small sample may also miss groups of children who have specific issues such as not having a computer at home or some primary schools who do not use computers as much as other primary schools in lessons. Equally, however, a very large sample of, say, 1000 students would be unlikely to offer any further opinions or experiences than a mid-size sample. It would also be difficult to ensure that the data was gathered in a consistent way because this number of students might be too many for one researcher to accommodate in the time allotted for the study. One further consideration when choosing the sample was that the students should not have experienced CAD before so that they did not already have pre-formed opinions and their experience of CAD would be consistent as it could be delivered in the same way by the same person.

To meet these requirements an induction day event at a large east of England school with good CAD facilities was chosen. The event provided the ideal setting for the study as it involved around 300 Year 6 (age 10–11) students from six feeder schools. None of the feeder schools currently teach CAD design; however, inclusion of students from this range of schools had the advantage of a varied experience of computer use in education. The event was spread over two days and involved groups of around 25 students rotating between six activities each lasting 45 minutes. This allowed 45 minutes for each of the 12 groups of students to participate in the pilot study. One of the activities involved the pupils making a key ring on a laser cutter. To achieve this, hand-drawn designs needed to be transferred to a CAD program. As time didn't allow for the pupils to create their designs on *Techsoft* 2D design, the feeder primary schools were asked to send in their designs prior to the event so they would be ready to be made and creativity could be assessed. During each session the pupils were given a demonstration of a 2D and a 3D CAD program. The pupils then watched their key rings being made on the laser cutter in groups of approximately six. They then added colour to their key ring and took them home. This task was chosen as it incorporated the students' designs and allowed them to see, if not experience, the entire process from design to the making of a tangible product that they could take home.

Over the two days in which the study took place 47 pupils were unable to attend; therefore the potential sample for the study consisted of 254 of the intended 301, including a relatively equal number of 124 girls and 130 boys. This number of students provided data from a wide range of student experiences without becoming unmanageable. The activity was delivered to all of the students over the two days by the same teacher and therefore remained consistent and the data was collected from all of the students who attended the event and who had not used CAD software before.

3.2.2 Pilot study questionnaire design

The large number of students and the range of data that was required from this study, along with the short amount of time that was spent with the students, limited the methods available to the researcher. Interviews and case studies were more suited to a far smaller sample, because although a good depth of information could be collected it would not be possible to obtain the views from a wide enough range of students, and selecting a sample would be difficult as not enough was known about them. The most appropriate method of collecting data from the students would be via a questionnaire. Walliman (2001) describes this method as a versatile and cost-effective research tool. The data gathered from the questionnaire is mainly quantitative in that the results are in numerical format. The benefits of this method are that a large volume of data can be collected and processed quickly and the results can be displayed in graph and chart format which can be clearly understood, especially if large differences in the data are established. A further advantage is that the questionnaire takes only a few minutes to complete and as it would be delivered as part of the day's activities it is likely that a very high number would be returned because the researcher could collect them in on the day, preventing the participants from forgetting to send them back. It is important to note here that it should be emphasised to the students what the questionnaire will be used for and that they do not have to complete it if they do not wish to.

Within the pilot study this approach led to 100% of the questionnaires from those students present on the day being returned. This is an unusually high return of questionnaires, probably because the students viewed the questionnaire as part of the task and also because the task was part of an induction day event and therefore the students were relatively eager to participate in all activities fully. This high return of questionnaires allowed for all students' views from the sample to be considered as part of the study. A concern when completing the questionnaire was that as the students were new to the school they may have wanted to create a favourable first impression by choosing a response that they believed the teacher wanted to hear. A further concern was that they may have wanted to give responses that they believed their friends had given in order to gain favour with those friends. To reduce the likelihood that these responses may be given, it was impressed upon each group as they were given the questionnaire that there was no 'right' or 'wrong' answer and that improvements could only be made if we had an accurate understanding of how students felt about using the software. Twenty minutes before the end of the session, while students were sitting at their desks, they were all given the questionnaire and basic instructions as to what was expected of them, such as first and last name and an example of which end of the scale they should select for which response. The occasion was informal – it was not a test – and students were allowed to talk. It is possible, therefore, that a student may have selected answers based on their friends' responses; however, because the tight time restriction of 5–6 minutes there was little time for any discussion.

The questionnaire consisted of nine questions, five of which related to how the children expected to enjoy or not enjoy using CAD as well as how hard they expected to find using it. These five questions used a Likert scale (Likert, 1932) for the children to select an answer from. The Likert scale was chosen not only because of the time constraints, ticking a box is quicker than writing, but also because the study involved children. Often, when asked to evaluate a product or experience children will use one word answers such as 'good', 'fun' or 'rubbish'. This type of answer is hard to categorise and difficult to compare later responses to as well as being difficult to develop an understanding of how good, fun or rubbish they had found the experience. The use of a scale forces students to make a choice to a certain extent rather than saying 'don't know', although the use of a five-point scale does give the students an opportunity to choose a middle option of neither like nor dislike or neither find easy nor hard. By using this method it is easier to process the information, as the data is clearly grouped into a limited number of results.

Three further questions on the questionnaire were simple yes or no answers relating to previous CAD use and computer use. One question asked students to indicate how many hours they used the computer in a week. This also used a scale for the same reasons the Likert scale was used; however, it was a factual question rather than an opinion and had a larger number of responses to choose from. The final part of the study involved a very short spatial awareness test consisting of five questions in which the students had to mentally rotate shapes to find an identical shape from a choice of four others. This type of test was used because it mirrored the spatial actions used in CAD most accurately whereby it is necessary to rotate shapes mentally in order to model them well. The test was kept short at ten minutes in order to keep within time limitations and also to avoid overwhelming the students who may again have become concerned that they needed to perform well in order to be accepted into the new school. Little advice was given at the start other than asking the students to write their first and last name and showing an example of the type of question on the paper and how to answer it. The length and setting for this test may have reduced the validity of the results; however, as time only allowed for five questions and due to the number of students, silent and well-spaced test conditions were not possible. The intention of the test was to establish whether spatial awareness was worth including in more detail in later parts of this research.

3.2.3 Questions

The first information provided by the students on the questionnaire was their name. The purpose of this was to be able to identify the student and therefore allow data gathered at a later date to be compared to the original data gathered during the pilot study. When documenting any data in the research the names were abbreviated to their initials in order to protect their identity. One alternative was to give the student a number because this may make them more likely to be honest with their answers if they feel they are less identifiable. However, this may also be considered unethical as the student would be identifiable and giving them a number may lead to false assumptions on the student's part that they are not. Due to the large amount of students involved in the study it would also be difficult to compare data gathered at a later date because the number would have to match previous questionnaires in order to find it. The students were also asked to indicate their gender on the questionnaire. This is because research has established that girls approach computer work differently to boys and would therefore benefit from a different approach to teaching it (Collis, 1985; Culley, 1988; Turkle, 1984; AAUW, 2000; Valentine and Holloway, 2000; Carter 2010; Stoilescu and Egodawatte 2010; Carbonaro et al. 2010). By being able to separate their answers by gender the researcher can establish whether any intervention affects boys and girls differently.

The first question asked whether the student had used CAD before. From the results of this question any student who had used CAD before could be treated separately from those who hadn't. The purpose of this was that they may have already established preferences based on their experiences.

The second question asked the students how many hours they currently used the computer. The intention of this was to establish whether those who were the most familiar with using computers were also the most likely to expect to enjoy using 3D SMCAD programs and also whether they expect to find using CAD easier than those who were less familiar with computer use. This considers research from Valentine and Holloway (2001) who believe that children can be grouped into those who don't like using computers and those who do. These groups are further defined by type of computer use.

The third question asked whether the students had a computer at home. This also related to how familiar the students were with computers, although the data from this cannot be considered on its own as it assumes that if the child owns a computer they will be more familiar with its use. This may not actually be the case as owning a computer does not indicate usage but combined with asking how many hours the students uses the computer for, including other computers such as the ones at school, may create a better understanding of how familiar students are with computer use.

The following questions consider difficulty and emotion. Several possibilities presented themselves when considering emotions, such as confidence, enjoyment and attitude. Level of enjoyment was chosen because a review of the literature suggests that the student must expect to experience positive emotions such as enjoyment when using the software in order to be motivated to learn it.

The first of these questions asked the students to indicate how hard they believe a 2D design program is to use and how much they expect to enjoy using it. These results need to be considered in conjunction with the next two questions, which also use the Likert scale and ask the student to indicate how hard they expect a 3D SMCAD program will be to use and how much they expect to enjoy it. The purpose of this was to establish whether the students were able to identify that one program is more difficult to use than another and if they would expect to enjoy the easier or the more difficult program.

A final question asked the students if they believe that they will enjoy using the program more, less or the same if they made a product. The purpose of this question was that although producing a made product is not a necessary component in using 3D SMCAD to design, the researcher has noted that less able students appear to develop some confidence when making something by using CAD/CAM, as the resulting piece often has a higher quality than one they have made by hand.

Finally the students' creative ability was assessed by a panel of three teachers. The teachers on the panel were experienced in assessing work against National Curriculum and GCSE criteria and also in assessing work for creativity according to the definition established in the literature review. Two of the teachers were especially keen to encourage creativity in schools.

This assessment was undertaken on the hand-drawn key ring designs submitted by the students prior to the induction day and was separated into five categories by a panel of three experienced teachers according to the preset criteria outlined below:

- Level 5 – Students used one of the shapes given in the example and only added simple text as a design.
- Level 4 – Students used one of the shapes given in the example and had added a simple known logo such as the Nike tick and/or some simple text.
- Level 3 – Students used one of the shapes given in the example but had drawn a simple pattern or a single known design on it such as a football.
- Level 2 – Students used one of the shapes given in the example but had applied combinations of pattern and design in an interesting way.

- Level 1 – Students changed the shape of the key ring to be different to the example and had applied combinations of pattern and design in an interesting way.

3.3 Findings

As computer use in both the home and school has changed significantly over the past decade the first questions in the survey intended to determine how many students now own a home computer and how much they use computers on a weekly basis. The first question revealed that 93% of the students have a computer at home. This is a significant increase from the 53% of 6- to 17-year-olds who had computer access at home noted in the study by Livingstone and Bovill in 1999. While one might expect a significant change over this nine-year period, the figure of 93% is worthy of note. Those without a computer are now severely in the minority and may now feel excluded, especially considering the popularity of chat and email. This consideration should, perhaps, be included in further study.

Those using the computer between 1 and 5 hours a week either at home or at school accounted for 60% of the students, the remaining 40% was split fairly equally between 6 and 16-plus hours with 15% using the computer between 6 and 10 hours, 11% between 11 and 15 hours and 13% 16 hours or more. What is not evident from this research is in what capacity the students use the computers. A considerable portion of the amount the students use the computers could be for gaming or email. As there may be a relationship between type of computer use and how comfortable the students feel when using CAD a question determining type of computer use should perhaps be included in future studies.

Following research in America in 2000 (AAUW, 2000) which reported growing evidence of a lack of interest and participation in computer activities by girls, the data collected was separated to consider whether attitudes and computer usage had changed in the last eight years. The data showed that a larger percentage of girls used the computer between 1 and 5 hours compared to boys, that more boys used the computer for between 11 and 15 hours, and that a similar number of boys and girls used the computer for 16 hours or more a week (see Table 3.1).

Table 3.1 Computer use by Year 7 students both at home and at school

	Boys	Girls
1–5 hours	53%	67%
6–10 hours	19%	11%
11–15 hours	15%	8%
16+ hours	13%	14%

This suggests that the divide previously noted between boys and girls use of computers may be less of an issue than it had been; however, there still appears to be a difference in the amount of time boys and girls use computers and possibly the type of computer use may vary between girls and boys. Further research would be needed to establish whether this is significant. It is possible that the introduction of more female-friendly computer games, role-play activities and more interactive games which allow families to play together, in addition to the recent popularity of social websites such as Facebook and Twitter may have helped to bridge the gap which previously existed. This difference in use could affect how girls and boys feel about using complicated CAD programs.

To assess whether familiarity with computer use led to an increased level of expected enjoyment or a decreased level of expected concern regarding the difficulty of using CAD, the amount of time students spent using a computer was then cross-tabulated with their expected levels of enjoyment and difficulty when using *ProDesktop*, a 3D design package commonly used in schools (see Table 3.2).

***Table 3.2 Amount of computer usage compared to expected enjoyment when using* ProDesktop**

Computer use	1 – expect to enjoy	2	3	4	5
0–5 hours	32.21%	34.62%	26.15%	6.25%	0.77%
6–10 hours	37.14%	35.26%	15.27%	9.47%	2.86%
11–15 hours	42.31%	30.77%	23.08%	3.84%	0%
16+ hours	54.54%	18.18%	27.28%	0%	0%

Those who used the computer 16 hours or more expected to enjoy using *ProDesktop*, with all students selecting between 1 and 3 on the enjoyment level scale. These students also selected the greatest number of 1s therefore indicating a high level of expected enjoyment. Those using the computer for 6–10 hours selected the greatest number of 4s and 5s therefore indicating a lower level of expected enjoyment, although the majority still selected between 1 and 3 on the enjoyment scale. Therefore familiarity with computer usage does appear to increase the level of expected enjoyment when using CAD.

Students who use computers for 16 hours or more selected a higher number of 4s and 5s when considering how difficult it will be to use *ProDesktop* (see Table 3.3). This shows that although these students are familiar with computer use and expect to enjoy using *ProDesktop* they expect to experience difficulty when using it. One theory for this could be that they have a more realistic understanding of computer systems, a further theory may be that these students enjoy using computers for gaming or social use but find educational use hard. Further research would be needed to determine a reason for these results.

Table 3.3 also shows that those who use computers for between 11 and 15 hours selected the most 2s and therefore expected that using *ProDesktop* would be reasonably easy. This may indicate an indifference to computer usage in that they use computers a significant amount and see them as no more difficult than any other program they use.

***Table 3.3 Amount of computer use compared to expected difficulty when using* ProDesktop**

Computer use	1– easy	2	3	4	5 – hard
0–5 hours	5.38%	11.54%	40.77%	31.54%	10.77%%
6–10 hours	5.81%	12.53%	46.82%	22.96%	11.88%
11–15 hours	3.85%	23.08%	46.15%	23.08%	3.84%
16+ hours	4.55%	13.64%	36.36%	27.27%	18.18%

Techsoft 2D design is a relatively simple program to use. The intention of the next set of questions is to consider whether students expect to find all CAD systems difficult or whether they expect a difference in enjoyment or difficulty levels between the easier 2D design and the more complex 3D design programs. Most students expect to enjoy using *Techsoft* 2D design with very little difference between male and female responses (see Table 3.4).

The pattern of responses relating to the expected enjoyment of using *ProDesktop* are similar to the expected enjoyment of using 2D design; however, a greater number chose 2s and 3s indicating that the students expect not to enjoy using *ProDesktop* as much as 2D design.

Table 3.4 Expected enjoyment when using 2D design

	Girls	Boys
1 – expect to enjoy	23.2%	27.8%
2	13.6%	12.6%
3	6.8%	6.8%
4	2.5%	4.2%
5 – expect not to enjoy	0%	2.5%

Those who chose between 1 and 3 on the Likert scale indicating that they expect using 2D design to be reasonably easy accounted for 91% of students (see Table 3.5).

Table 3.5 Expected level of difficulty when using 2D design

	Girls	Boys
1 – easy	8%	11.2%
2	13.2%	15.2%
3	21.2%	22.8%
4	2%	4.4%
5 – difficult	0.8%	1.2%

More students chose between 3 and 5 when stating how difficult they expect using 3D CAD will be indicating that more students expect to find the 3D CAD program harder to use. This can be seen more clearly in Table 3.6 below and implies that some students do understand that there is a difference in the complexity of the two programs and also that, when compared to expected enjoyment of the two programs, many expect that they are more likely to enjoy using the more simplistic program.

Although the results have been shown separately in the tables above, Table 3.6 below displays these results side by side to allow them to be more easily compared.

The differences between expected level of enjoyment and difficulty show that a greater number expected to enjoy using *ProDesktop* (despite expecting to find it difficult to use) than expected not to enjoy using it. Within this it was necessary to consider whether the results changed depending on whether they selected higher or lower numbers.

Using 3D CAD systems involves mentally and visually manipulating and rotating objects. Rynne and Gaughran (2007) believe that improving cognitive modelling will result in improved ability to extract and use procedural knowledge as well as command knowledge. A study by Lang et al. (1991) suggests that CAD expertise can be differentiated by this procedural knowledge. The next set of questions intends to study whether those who scored better in a short spatial awareness test found *ProDesktop* more enjoyable and easier to use (see Table 3.7 below). The test does not show whether spatial ability is linked to their actual ability to use 3D SMCAD software, however.

***Table 3.6 Comparison of expected enjoyment and level of difficulty between 2D design and* ProDesktop**

	2D design expected difficulty level	Expected enjoyment when using 2D design	*ProDesktop* expected difficulty level	Expected enjoyment when using *ProDesktop*
Girls choose no. 1	8%	23.2%	1.2%	17.9%
Boys choose no. 2	11.2%	27.8%	3.1%	19.6%
Combined no. 1 choices	**19.2%**	**51%**	**4.3%**	**37.5%**
Girls choose no. 2	13.2%	13.6%	5.4%	14.7%
Boys choose no. 2	15.2%	12.6%	6.9%	16.3%
Combined no. 2 choices	**28.4%**	**26.2%**	**12.3%**	**31%**
Girls choose no. 3	21.2%	6.8%	25.6%	12.6%
Boys choose no. 3	22.8%	6.8%	19.1%	11.3%
Combined no. 3 choices	**44%**	**13.6%**	**44.7%**	**23.9%**
Girls choose no. 4	2%	2.5%	12.8%	4%
Boys choose no. 4	4.4%	4.2%	14.8%	2.4%
Combined no. 4 choices	**6.4%**	**6.7%**	**27.6%**	**6.4%**
Girls choose no. 5	0.8%	0%	4.2%	0%
Boys choose no. 5	1.2%	2.5%	6.9%	1.2%
Combined no. 5 choices	**2%**	**2.5%**	**11.1%**	**1.2%**

Table 3.7 Spatial awareness test results

Spatial awareness test results	100%	80%	60%	40%	20%	0%
Girls	5.5%	8.5%	18.7%	8.9%	4.7%	2.6%
Boys	4.7%	13.2%	14.9%	10.4%	6.3%	1.6%
Combined	**10.2%**	**21.7%**	**33.6%**	**19.3%**	**11%**	**4.2%**

Most students scored between 60 and 100% in the spatial awareness test (see Table 3.8 below), with little difference in the results of boys and girls. Spatial ability seems to make little difference to expected enjoyment of using *ProDesktop*, as the patterns of between 1s and 5s are similar regardless of the spatial awareness results, with the exception of those scoring 60 and 20%. Those scoring 60% selected a far higher number of 2s and 3s and a lower selection of number 1s. This indicates those in this band expect not to enjoy using *ProDesktop* as much as those in the other bands. Those scoring 20% have selected no 4s or 5s and although there is a reduced number of 2s the results generally indicate that those in this band expect to enjoy using *ProDesktop*.

The next set of questions considers whether the boys or the girls were more creative and whether those pupils who produced more creative work also did better on the spatial awareness test. Creativity was assessed by a panel of three experienced Design and Technology teachers. The panel was chosen because of their knowledge and experience of assessing work for creativity against National Curriculum and GCSE criteria and because they have a firm understanding of what is considered to be creative work in a school situation in accordance with the definition of creativity stated in Chapter 2. Two of the panel have a keen interest in ensuring creativity is encouraged in Design and Technology lessons and have been working towards this goal for the past three years.

***Table 3.8 Comparison of spatial awareness test results and expected enjoyment when using* ProDesktop**

	1 – enjoy	2	3	4	5 – not enjoy
100% boys	2%	2%	0%	0.4%	0%
100% girls	2.4%	0%	2.8%	0%	0%
Combined	**4.4%**	**2%**	**2.8%**	**0.4%**	**0%**
80% boys	6%	3.6%	1.6%	0.8%	0.4%
80% girls	2.8%	2.8%	2%	0.4%	0%
Combined	**8.8%**	**6.4%**	**3.6%**	**1.2%**	**0.4%**
60% boys	3.2%	5.6%	4%	0.8%	0.4%
60%girls	4.8%	6.4%	4.4%	2%	0%
Combined	**8%**	**12%**	**8.4%**	**2.8%**	**0.4%**
40% boys	4%	2.8%	2%	0.8%	0%
40% girls	3.6%	2.8%	2%	0%	0%
Combined	**7.6%**	**5.6%**	**4%**	**0.8%**	**0%**
20% boys	3.2%	0.8%	2%	0%	0%
20% girls	2%	0.8%	1.6%	0%	0%
Combined	**5.2%**	**1.6%**	**3.6%**	**0%**	**0%**
0% boys	0.8%	0%	0.4%	0%	0.4%
0% girls	0.8%	0.8%	0.4%	0.4%	0%
Combined	**1.6%**	**0.8%**	**0.8%**	**0.4%**	**0.4%**

When assessing creativity very few students displayed a high level of creativity, with most choosing very simple, risk-free designs for their key rings. These ranged from those at level 5 who chose one of the standard shapes offered and only added their names or initials as a design to those at level 3 who had added some simple shapes or patterns to the design. These often included familiar logos or team names. Those scoring level 1 or 2 had added pattern and shape in an interesting way without merely copying those familiar to them (see Table 3.9).

A higher number of those scoring 80% achieved a level 2 for creativity than any other spatial ability level. Those scoring 0% and 40% on the spatial ability test failed to achieve higher than a level 3 for creativity. The only two students who scored a level 1 for creativity appeared in the relatively low spatial ability levels of 20 and 60% (see Table 3.10).

Table 3.9 Assessment of creative outcome

	Boys	Girls
Level 1	0.7%	0.7%
Level 2	4.7%	3.4%
Level 3	14.8%	10.1%
Level 4	13.5%	21.1%
Level 5	16.8%	14%

Table 3.10 Comparison of spatial ability and creative outcome

	Level 1 creativity	Level 2 creativity	Level 3 creativity	Level 4 creativity	Level 5 creativity
0% spatial awareness	0	0	2	4	5
20% spatial awareness	1	1	3	4	4
40% spatial awareness	0	0	9	10	12
60% spatial awareness	1	3	10	18	9
80% spatial awareness	0	8	8	12	3
100% spatial awareness	0	1	4	6	3

3.4 Summary

Many students were able to identify that not all CAD programs are the same and many felt that 3D CAD is a more difficult program to use than the standard 2D programs used in schools. More students expected to enjoy using the more simplistic program rather than the more complex one; however, a majority of students also expected to enjoy using 3D CAD despite anticipating it being difficult to use. Familiarity with computers increased the amount that students expected they would enjoy using 3D CAD as well as, surprisingly, an increase in how difficult they expected to find it to use. Although spatial awareness is an important aspect of designing with 3D CAD, it made little difference regarding expected enjoyment when using 3D CAD or to creative ability. In order to focus future studies most effectively it is necessary to establish which of the concerns raised in the previous chapter are the most relevant. The following outlines how the results compare to issues identified in the literature review.

Does the student's perception of their own ability and ease of use of the program change their ability and attitude to using the program?

Students were aware that there was a difference in the complexity of the two programs and this led to a difference in expected enjoyment when using the more complex 3D CAD program. Students not only expected to find using 2D design easy but also expected to enjoy using it. When observing them using the program later, the students also quickly achieved a reasonable level of ability. This may be due to them wanting to take 'the easy option' or that they are nervous of using the more difficult program. As the more simplistic program presented the least concern for the students it is therefore reasonable to focus further research on concerns experienced when learning the more complex 3D SMCAD program.

Does the amount of computer use including access to computers outside of school affect ability and attitude to using 3D SMCAD programs?

Nearly all students now have access to computers outside of school and therefore this presents less of an issue than it may have in the past. Although it is not necessary to include this in further studies at this stage the amount of computer use is worthy of further consideration in other, future studies. Those using the computers the most expected to enjoy using the complicated program more, although they also expected to find it harder to use. This could be due to a number of reasons such as a more realistic understanding of the program or liking a challenge, or it could be due to the type of computer use.

Historically gender has affected attitude to computer use. Do some students respond better to different teaching methods such as CSCL?

Gender and computer activity has been the subject of a considerable body of research since the introduction of computers. This research has frequently shown that females approach computer activity differently, with them appearing to underperform because the activities do not suit them. The data that resulted from comparing male and female responses on the questionnaire produced surprising results as there was little difference between them. This may be due to the fact that gaming, social use and educational activity has changed and now suits girls as well as boys, and therefore the divide is now much smaller than it had been originally. To fully establish the reasons for this it would need to be studied through separate research. As type of use was not determined by this study, it may be that girls and boys approach learning CAD differently and teaching CAD may also still need to be considered separately to achieve the best results. Gender difference will therefore be included in further studies included in this research.

Do the students expect to enjoy using the software more if a product is made at the end?

Those who felt that they wouldn't enjoy using CAD any more or less if they made a product accounted for 68% of students, 13% thought they would enjoy using CAD more if they made a product and 19% felt they would enjoy using CAD less if they didn't make anything. In this study the students did make a product and take it home with them. The students who had made key rings were asked who still had them and 32% still had the key ring they made two years after the induction day event, which indicates some pride or sentimentality attached to the product. If the students hadn't actually made a product at the end, it is possible that they may have a different viewpoint. Further research would be necessary to determine this.

Does spatial ability affect expected enjoyment or difficulty when using CAD software?

The spatial awareness test taken by the students did not follow strict test guidelines in that students did not complete the test in silence and were not made to sit a wide distance apart due to time and space restrictions. This could have allowed some of the students to copy to a certain extent and therefore make the results less valid. The test was also quite short and a longer test may mean some change in the results. The results of the spatial awareness test, however, did not reveal a significant difference when compared to expected enjoyment, expected difficulty or creative ability. Those who were most creative did show a slight increase in expected enjoyment, but the small extent of the increase would suggest that it would not be appropriate to continue to study this factor in terms of this research as other aspects provided more interesting data. This is not to say that spatial ability when compared to CAD use is not relevant and not worthy of future study as there were some changes in the results; however, within the limitations of this study it is not necessary to include it at this time.

Can students be creative using traditional and computer-based techniques and does perception of difficulty and enjoyment affect the creativity of the final outcome?

Despite an emphasis on creativity in schools highlighted by previous initiatives, the extent of creative ability shown was quite low. This was without also considering the complications that using difficult software would bring. The challenge of how to help children to be more creative when using CAD is therefore very significant and not only needs to be included in further study but should be one of the main focuses of the research as it includes two of the recent changes to the curriculum.

Considering the results of this research and how it compares to previous concerns, the focus of future studies will be to establish whether better strategies can be established to aid Key Stage 3 students to learn 3D SMCAD programs more effectively. This will include the effects of providing positive emotional experiences and how programs of study can be made to appeal to both girls and boys. A second focus to the research is in what ways students can be helped to be more creative when using 3D SMCAD.

3.5 Research questions

The pilot study was essential in providing a more focused approach to the research and has facilitated the creation of more precise research questions which are:

1. Can a more strategic-based intervention improve teaching and learning of 3D SMCAD programs?
2. Can computer-supported collaborative learning improve the teaching and learning of 3D SMCAD programs?
3. Can students be helped to achieve more creative outcomes when using 3D SMCAD?

Chapter 4 Methodology

4.1 Introduction

The purpose of this chapter is to provide a rationale for the research methods used to study the effects of a new strategy to teach Key Stage 3 students complex solid modelling CAD programs. The programme of research is an intervention study within an action research framework. Initially the chapter outlines the rationale for choosing an action research approach and examines the associated limitations of this type of study. It then presents an examination of the research methods used within each of the five studies which make up the programme of research. The chapter ends by outlining how these methods were considered suitable for fulfilling the aims of the research.

4.2 The aims of the research

Given the overall aims of the action research in Chapter 1, the specific aims of the action research are:

- To generate knowledge of teaching and learning methods that can improve students' learning of complex solid modelling CAD programs.
- To consider in what ways the teaching and learning of CAD/CAM, specifically 3D solid modelling software in secondary schools can be enhanced to allow children to use it more creatively.

These aims partly derived from the pilot study discussed in the previous chapter but they were also informed by observation of Design and Technology lessons in a large secondary school over a period of ten years which saw the introduction of CAD to the school.

Previously it was noted that students struggled to learn complex CAD programs and that they therefore also struggled to be creative in their designing when using this medium. These problems became more relevant for further investigation when creativity was included in both Key Stage 3 and Key Stage 4 of the National Curriculum on the recommendation of education experts such as Robinson (2001) and Craft (2005) who consider teaching children to be creative an essential part of education. The literature review reveals gaps in understanding of the problems students face, confirming that the above aims could guide valuable research into enhancing the teaching and learning of CAD in schools.

4.3 Research approach

Initial investigation of various research approaches identified that more than one may be appropriate to this study. In Chapter 3, which reported on a pilot study, a survey approach gathered a significant amount of quantitative data from a large sample of students. This has allowed a more focused approach to the following study by identifying the most relevant issues that affect students using complex software in schools, which could be further investigated using other methods. As emotions and attitude form a significant part of the study a survey was unable to identify why the student felt the way they did and approaches which gather qualitative data were more appropriate.

A case study with the researcher observing a small number of students over a period of time may provide an in-depth understanding of the reasons students appear to struggle to both use and be creative with the software. Variables such as individual backgrounds of the students involved and mood at the time could be taken into account throughout the research. Limitations of this approach are that a focus on a small number of students may not be representative of a larger group and any improvements to teaching strategy may only be effective to this group of students and not in a classroom situation.

An ethnographic approach with the researcher as a participant in the study would have the benefit of being able to consider the views of the instructor within the research and allow an immediate response as situations present themselves. The main disadvantage of this approach is that the level of participation that would be necessary would make observation and detailed note-taking extremely difficult. Again the research would be limited to a relatively small number of students and the views of other instructors or schools could not be easily included.

As action research focuses on improving practice, and it is possible for the researcher to also be the practitioner, this approach appears to be the most appropriate. Within this, methods such as small-scale surveys and more focused groups can be studied while also considering the views of the instructor and of other classes and schools.

4.4 Action research

Macintyre 2000 defines action research as:

> An investigation, where, as the result of rigorous self-appraisal of current practice, the researcher focuses on a 'problem' (or a topic or an issue which needs to be explained), and on the basis of information (about the up-to-date state of the art, about the people who will be involved and about the context), plans, implements, then evaluates an action then draws conclusions on the basis of the findings. (p1)

An important aspect of action research is its iterative approach, which allows studies to be repeated using similar methods. Thus results can be checked and rechecked establishing the reliability of the study (see Figure 4.1).

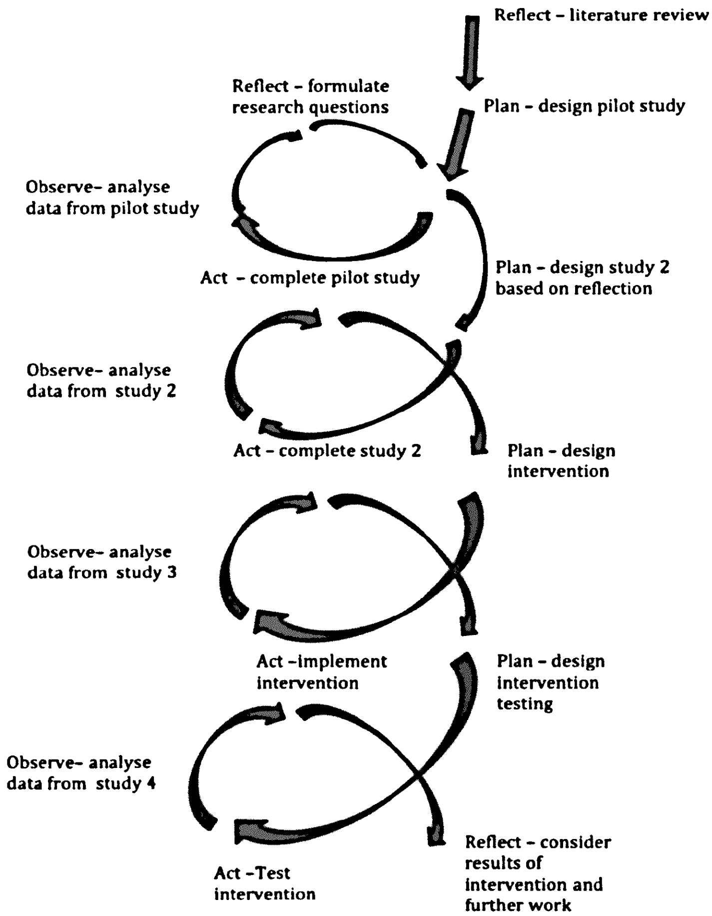


Figure 4.1 Action research diagram of programme of study adapted from http://celt.ust.hk/teaching-resources/action-research

In this case the researcher, a Design and Technology teacher with considerable experience of teaching 11- to 18-year-olds, adopts an action research approach and is able to reflect on current practice, develop strategies and, through careful evaluation, is able to influence the current teaching and learning of CAD in Key Stage 3. It may be difficult to see how this differs from what teachers do already in that most teachers evaluate and try to improve on current practice within their own classroom. The difference is explained by Mukherji and Albon (2010) who state that 'it might be easy to confuse action research with what practitioners do anyway – reflecting upon and improving their practice'; however, 'the distinction is seen in praxis, which is the idea that theory and practice are inseparable'. The difference between action research and what practitioners do is important because 'an understanding and application of theory to practice and practice to theory is important to action research but not necessarily a *routine* part of every practitioners' daily work' (p 93). This type of research has many advantages not least of which is that the researcher has access to a large amount of potential subjects over a long period of time through normal lesson activities. This reduces the likelihood that any of the chosen sample would not participate in the research, as it is not seen as anything other than normal work. Students should, however, be informed that they are participating in research and be allowed the opportunity to withdraw if they wish. Although some students may wish to be excluded from certain aspects of the research, such as being interviewed, it is unlikely that many, if any, students will withdraw from the whole study, as it forms part of their normal lessons. The action research approach also allows the researcher to be flexible and respond to problems that may occur during the research process. For example, Macintyre (2000) writes that if the pupils are tired or restless at one particular time of day then the activity can be moved to a more appropriate time. She also writes that action research is realistic because the researcher has 'intimate knowledge of the context allowing them to gauge what needs to be done, and what can be done amidst all the other pressures of the classroom day'. The action research approach is not without limitations, however. Mukherji and Albon (2010) warn that as an 'insider' it is important to set boundaries around what you will and will not document. This is because in a one-off interview the interviewee is clear about the terms under which the interview is taking place; however, as an 'insider' it would be tempting to report things said in informal settings which may not be ethically acceptable if the participants do not understand what they are unwittingly participating in.

4.5 Ethics

All of the studies in this programme of research involve people as participants. This creates potential issues regarding ethics which are different to studies involving products. To remain ethical a stance needed to be established prior to the studies taking place.

In order to protect the people taking part in the studies the schools are not named in the research and both teachers and students are only identified through their initials on all material gathered. Permission was sought from the head teachers of the schools for the research to take place. In addition, home school contracts are used by the school to establish certain expectations such as uniform and homework; however, these contracts also give parents the option for their child not to participate in studies such as these or to have their photographs appear in publications linked to the school. All parents of students who participated in this study had given permission for them to do so through this home school contract. Although students work is presented in this study no photographs of students appear, as this would identify them, which the researcher was trying to avoid in order to promote participation. All teachers involved volunteered for the study and were made aware that they could leave the study at any time. In a similar way all of the students were informed prior to the studies taking place that they did not have to participate and could also choose to opt out at any point. This was especially important before any interviews took place as some students may not have wished to be recorded in any way. To protect their identities students were told that only their initials would be used and as the interviews were recorded the students were told that only the researcher would listen to the recordings. This was very strictly adhered to. As most of the studies took place through normal school lessons, the students were not inconvenienced in any way and as they were used to being assessed throughout their work no one refused to be included in the studies and only one student chose not to be involved in the interviews that took place.

4.6 The research venue

One of the initial problems to consider was where the study should take place. The school needed to allow a large number of students frequent access to 3D SMCAD programs over the course of at least a two-year period. Students who had already used CAD may have already formed positive or negative opinions about the software and therefore any interventions offered may have reflected their preconceived ideas. As such, the sample needed to be large enough to gain a variety of responses from students who had only recently experienced 3D SMCAD software and who had not yet formed opinions of CAD programs through using them. The teacher delivering the programme of study would, in the initial studies, need to remain the same to ensure the delivery of the programme was consistent and did not influence the outcome of the research. The teacher would also need to have some experience in teaching 3D SMCAD in order to keep student perception of the instructor's knowledge constant, which has been shown in studies to influence student outcome (Pektas and Erkip, 2006).

Fortunately initiatives that have involved including IT in all subjects in school (DfE, 1999), the Key Stage 3 strategy which included improving ICT capability (DfE, 2002) and the CAD/CAM in Schools programme also introduced around this time have increased the amount of schools that could fit this criteria. One of these schools, a large secondary school in Cambridgeshire, is the school in which the researcher is employed. This fits well within the understanding of action research. That is, using this school as the venue for the research programme would have the advantage of having a researcher on-site who is able to ensure which teacher has which classes in order to control the element of maintaining the studies being delivered by the same teacher, so minimising any variations when teaching the unit.

The school has approximately 1700 students on roll. None of the feeder primary schools currently have CAD facilities and therefore there is little risk that many of the new intakes of students had previously had experience of using CAD. Therefore students just starting Year 7 would be the most appropriate year group to participate in the study. The school intended to be used for the study has a new intake of around 300 Year 7 students each year, which would be a large enough number to gain a large amount of data without the data being unmanageable. This would also remove any concerns regarding selecting a sample, as the whole year group could be included in the study.

In addition to this both 2D and 3D CAD programs had been taught to Year 7 through to Year 13 students for the past five years through dedicated programmes of study and five of the Design and Technology teachers had sound CAD knowledge and experience of teaching it to students. The CAD facilities included a CAD suite containing 25 computers with both 2D and 3D software installed and a further two Design and Technology classrooms containing 15 computers each with solid modelling CAD software installed that students have access to.

4.7 Study 1 – Pilot study

As discussed in Chapter 3 a pilot study was undertaken at the chosen venue to focus the research aims by establishing the most relevant aspects to Key Stage 3 students learning CAD software today. A detailed description and analysis of research methods are included in Chapter 3; however, a summary is also included in this chapter.

4.7.1 Pilot study sample

To examine the issues surrounding CAD use in schools a reasonably large sample was needed to gain a variety of opinions and data as well as the inclusion of students from a wide range of ethnic and social backgrounds. The sample was not too large as to make handling the data too difficult but included a large enough sample that represented a wide range of opinions and backgrounds. The students should also not have experienced CAD before so that they did not have pre-formed judgements.

To meet these requirements, an induction day event at a large east of England secondary school with good CAD facilities was chosen. The event provided the ideal setting for the study as it involved around 300 Year 6 (age 10–11) students from six feeder primary schools. The students visited the secondary school for day rotating between six activities prior to enrolling at the school a few months later. None of the feeder schools currently teach CAD; however, inclusion of students from this range of schools had the advantage of a varied experience of computer use in education. Over the two days of the event the sample for the study consisted of 254 of the intended 301, including a relatively equal number of 124 girls and 130 boys.

The activity started with students being given a demonstration of a 2D and 3D CAD program. The students then watched their key ring designs, which they had previously submitted, being made on the laser cutter. This allowed them to experience the CAD/CAM and take a product home at the end of the day.

4.7.2 Pilot study questionnaire design

Due to the large number of students and the range of data that was required from this study, along with the short amount of time that was spent with the students, the most appropriate method of collecting data was via a questionnaire. A large amount of quantitative data was gathered that could be compared against data collected in later studies easily and could be completed quickly. The questionnaires were completed on the day of the event and collected on the same day, which led to a 100% return of the questionnaires.

A concern when completing the questionnaire was that as the students were new to the school they may have wanted to create a favourable first impression by choosing a response that they believed the teacher wanted to hear. A further concern was that they may have wanted to give responses that they believed their friends had given in order to gain favour with those friends. To reduce the likelihood that responses that have been influenced by their friends may be given, it was impressed upon each group as they were given the questionnaire that there was no 'right' or 'wrong' answer and that improvements could only be made if we had an accurate understanding of how students felt about using the software. Twenty minutes before the end of the session, while students were sitting at their desks, they all were given the questionnaire and basic instructions as to what was expected of them, such as first and last name and an example of which end of the scale they should select for which response. The students were allowed to talk and therefore may have selected answers based on their friends' responses; however, because of the tight time restriction of 5–6 minutes there was little time for discussion.

The questionnaire consisted of nine questions, five of which related to how the children expected to enjoy or not enjoy using CAD as well as how hard they expected to find using it. These five questions used a Likert scale (Likert, 1932) for the children to select an answer from. The Likert scale was chosen because it is quicker and prevents students from giving one word answers. A single word response is difficult to categorise and to compare later responses to as well as being difficult to develop an understanding of how 'good', 'fun' or otherwise they had found the experience. While the use of a five-point scale does give the students an opportunity to choose a middle option of neither like nor dislike or neither find easy nor hard, the responses can be easily grouped and analysed.

Three further questions on the questionnaire required simple yes or no answers relating to previous CAD use and computer use. One question asked students to indicate how many hours they used the computer in a week. This also used a scale for the same reasons the Likert scale was used. The final part of the study involved a very short spatial awareness test consisting of five questions in which the students had to mentally rotate shapes to find an identical shape from a choice of four others. This type of test was used because it mirrored the spatial actions used in CAD most accurately whereby it is necessary to rotate shapes mentally in order to model them well. The time allowed for this test was ten minutes and little advice was given at the start other than asking the students to write their first and last name and showing an example of the type of question on the paper and how to answer it. The length and setting for this test may have reduced the validity of the results; however, as time only allowed for five questions and due to the number of students, silent and well-spaced test conditions were not possible. The intention of the test was to establish whether spatial awareness was worth including in more detail in later parts of this research.

4.7.3 Questions

The first information provided by the students on the questionnaire, shown in Appendix 1, was their name; this was later abbreviated to their initials in order to protect their identity. The students were also asked to indicate their gender on the questionnaire so that the researcher could establish whether any intervention affects boys and girls differently.

The first question asked whether the student had used CAD before. The purpose of this was that they may have already established preferences based on their experiences.

The second question asked the students how many hours they currently used the computer. The intention of this was to establish whether those who were the most familiar with using computers were also the most likely to expect to enjoy using 3D SMCAD programs or find them easier to use.

The third question asked whether the students had a computer at home. This also related to how familiar the students were with computers.

The following questions consider difficulty and emotion. Several possibilities presented themselves when considering emotions, such as confidence, enjoyment and attitude. Level of enjoyment was chosen because a review of the literature suggests that the student must expect to experience positive emotions such as enjoyment when using the software in order to be motivated to learn it (Ahn, 2005; Spendlove, 2007).

The first of these questions asked the students to indicate how hard they believe 2D design is to use and how much they expect to enjoy using it. These results need to be considered in conjunction with the next two questions, which also use the Likert scale and ask the student to indicate how hard they expect a 3D SMCAD program will be to use and how much they expect to enjoy it. The purpose of this was to establish whether the students were able to identify that one program is more difficult to use than another and if they would expect to enjoy the easier or the more difficult program.

A final question asked the students if they believe that they will enjoy using the program more, less or the same if they made a product. The purpose of this question was to establish whether the students develop confidence if a high-quality product is made.

Finally the students' creative ability was assessed by a panel of three teachers. The teachers on the panel were experienced in assessing work against National Curriculum and GCSE criteria and also in assessing work for creativity according to the definition established in the literature review. Two of the teachers were especially keen to encourage creativity in schools.

This assessment was undertaken on the hand-drawn key ring designs submitted by the students prior to the induction day and was separated into five categories by a panel of three experienced teachers according to the preset criteria outlined below:

- Level 5 – Students used one of the shapes given in the example and only added simple text as a design.
- Level 4 – Students used one of the shapes given in the example and had added a simple known logo such as the Nike tick and/or some simple text.
- Level 3 – Students used one of the shapes given in the example but had drawn a simple pattern or a single known design on it such as a football.

- Level 2 – Students used one of the shapes given in the example but had applied combinations of pattern and design in an interesting way.
- Level 1 – Students changed the shape of the key ring to be different to the example and had applied combinations of pattern and design in an interesting way.

4.8 Study 2 – Examining student attitudes to existing teaching of CAD programs

Following the induction day event which formed the basis of the pilot study the students enrolled in the school two months later. Within the school Key Stage 3 students followed a carousel of Design and Technology activities lasting for three 50-minute lessons a week for six weeks. One of these activities involved the students learning 3D SMCAD in the traditional manner of step-by-step instruction, with the pupils following the teacher's instruction. Once the basic concepts had been completed in this way the students then had to design a robot on the computer using as many of the skills that they had learned as they could. A robot was chosen because this was requested by both male and female students when they were asked what they would like to design. One criticism of this is that images in the media are often quite similar. The stereotypical image of a robot is that it is quite square and the first image people think of is often one with a square body, square head and square feet rather than the transformers or technobot-style of robot. With this stereotype in mind it could be quite difficult to be creative within the task. To counter this, the students were asked to make suggestions as to what their robot could look like and the things they would like their robots to do before they started. These group ideas were written on the board to help them design a robot that might avoid the more obvious stereotype. One potential issue with this is that it is much easier on

ProDesktop to create very simple shapes such as squares and circles; therefore there may have been a tendency to stick to the square stereotypical robot design rather than try to be creative. They were allowed to refer back to notes that they had made and were not expected to remember exactly how to perform each action. This is the same method that has been used in the school for several years to teach 3D SMCAD. At the end of this period of study the students were again assessed in order to better understand how they viewed learning the program. Again the large numbers of students involved in the study ruled out many research methods in the first instance. One method considered was the use of diaries, where the students could write down what they had learnt during the lesson and how they felt about the lesson in terms of difficulty and enjoyment. To test how effective this method could be one class in another year group was asked to keep a diary and note new skills, feelings and achievements as they progressed. This method proved to be unsuccessful as it took up a large amount of time in the lesson. A further problem was that students were reluctant to elaborate on their experiences, often only using one-word answers. It was intended that a questionnaire would be used in addition to the diaries to provide a deeper understanding of their questionnaire answers. Ultimately a questionnaire was the most appropriate method in order to collect in a large amount of data quickly without disruption to normal lessons. From the results of this students could be selected to participate in interviews to reflect on their experiences in a more detailed way.

4.8.1 Study 2 questionnaire

At the end of the course the questionnaire that was given to the students was much shorter than the first, delivered in the pilot study, as questions that had been proven to be irrelevant to this research were removed. Those that remained kept the same format and wording as before in order to maintain consistency when comparing the results with the previous questionnaire results. In an identical way the students were informed of the purpose of the research and that no one else would see the research with their full name on it. The students were then given the option to decline from participating. As part of the lesson plan the students were required to complete an evaluation of their work and it was expected that they would see the questionnaire as an extension of this activity because the questions are quite similar.

The students were again asked to provide their full name on the questionnaire in order to make finding the results from it easier in the first instance. From this point, as before, data was written using initials only.

The first question asked the students to indicate on a five-point Likert scale how hard they had found *ProDesktop* to use. The intention of this was to establish whether student attitude pertaining to the actual level of difficulty when using *ProDesktop* changed from the expected level of difficulty indicated in the first questionnaire.

The second question asked the students to indicate on a five-point Likert scale how much they had enjoyed using *ProDesktop*. The intention of this was to establish whether student attitude pertaining to the actual level of enjoyment when using *ProDesktop* changed from the expected level of enjoyment indicated in the first questionnaire.

The final question asked the students to explain why they thought they had answered the questions the way that they had. The purpose of this was firstly to make sure they completed the questionnaire correctly as students can get confused and select the wrong end of the scale and also the information given could be grouped according to their answers. The answer to this question may also provide a more detailed insight into the reason the student feels the way they do, which could be used for selecting a sample or to help direct questions during an interview. When the students were grouped, however, this question was not chosen as the one they were grouped by, because the responses were too varied and often only one word answers had been used which made it difficult to gain any further understanding as to why they felt the way they had.

From the results of this research the students were grouped according to their level of enjoyment or extreme changes in attitude, and semi-structured interviews were conducted.

4.8.2 Semi-structured interviews

Interviews were then chosen as a method of research at this time as more in-depth information was required. A key advantage of this method is that it allows the interviewer to investigate areas of interest as they emerge and allows the participants to explain and clarify their thoughts and opinions (Robson, 1993). The information gathered can be both quantitative and qualitative in nature, although for the purposes of this study the information required is more qualitative and therefore the interviews were not highly structured in their design. To ensure that some standardisation was achieved all groups were asked the same set of questions (See Appendix 6); however, these were open questions which would allow for the participants to explain and clarify the reasons for their responses. This also allowed the interviewer greater flexibility to adapt the questions to suit the groups being interviewed. The sample for the semi-structured interviews was selected based on the enjoyment question in the questionnaire. The reason for this approach is that if students enjoy using the program it can be assumed that they will want to use it more frequently; therefore it would be most useful to find out in more detail why the students enjoy or do not enjoy using 3D SMCAD programs. When the students were grouped in this way certain types of student become evident:

- Those who expected to enjoy using 3D SMCAD and then did actually enjoy using it when they had experienced it.
- Those who expected to enjoy using 3D SMCAD but did not enjoy using it when they actually used it.
- Those who expected not to enjoy using 3D SMCAD but enjoyed using it when they experienced using it.
- Those who expected not to enjoy using 3D SMCAD and did not enjoy using it when they actually used the program.

The most extreme responses or shift in responses were the most appropriate to interview, as these students were more likely to have a clear understanding about why they felt the way they did.

By grouping the students in this way 35 students were selected to be interviewed. In reality this was too large a group to interview at one time because the students may not have had the time to give their opinion or may have felt intimidated by the amount of people present. A further problem may have been that as they held quite extreme views they may have felt unable to speak freely and give honest opinions. If the groups were too small a dialogue may not have occurred between them and they may not have felt that what they had to say was relevant. Having more than one student to interview meant that they would be able to exchange and discuss ideas. Students may be concerned that they could look silly in front of others and may not say anything but generally from experience they tend to build on others' comments if they feel comfortable enough. Groups of five or six pupils would be small enough to allow the data gathered to be able to be reported on with limited confusion. Too many students would make it difficult to work out who had said what, whether this be through written notes or taping the discussion. A further consideration was whether to group the students according to their similar views or mix the groups by including some that enjoyed using CAD and some that didn't. One advantage of mixing the groups is that the views are likely to be dissimilar and this would therefore promote a more varied argument within the groups. Grouping the students according to their similar views is advocated by Johnson and Christensen (2008) who write that homogenous groups are more likely to promote discussion than groups which are dissimilar to each other. As this study is interested in why the students feel the way they do and children are often concerned with peer opinion it is likely that the students would be more comfortable speaking in similar groups; therefore groups of five or six students with similar opinions were chosen for this study. By creating small groups in this way six interviews needed to be conducted in the following group types:

Group 1 – Significant increase in enjoyment.

Groups 2 and 3 – Expected to enjoy using CAD and did enjoy using it.

Groups 4 and 5 – Expected not to enjoy using CAD and didn't enjoy using it.

Group 6 – Significant decrease in enjoyment.

In order for the students to be open they needed to feel relaxed and consider it is privilege to be included in the study rather than it being something that was to be endured. For this purpose the room setting was quite important. The most appropriate room available was one the students were familiar with and that had an 'easy' seating area so that it felt less like a lesson and more like a friendly chat. The room chosen for the study was large, had good lighting, was colourful and had reasonable ventilation and helped the students to feel physically comfortable. To further ensure that they felt the experience was a treat, squash and biscuits were offered and the interviews took place during normal school lesson time rather than in their own time. It is important to note, however, that no other students apart from the group were in the room so that they were not disturbed in any way. In order to achieve this, the interviews were conducted over three different days at different times of the day. It is possible that the variables associated with this may affect the students' responses as at certain times of the day some students may feel more hungry or tired than at others or different weather on the day may affect mood. Providing food and drink in a relaxed atmosphere minimised this effect, however, it was not felt these factors made a significant difference to the students' mood during the interviews. A final factor to consider was the length of the interview. Too long and the students may get bored, too short and the students may feel rushed. Lessons in the school where the study took place are 50 minutes long and it seemed reasonable to keep within this time frame as the students were familiar with it. Thus 30- to 40-minute interviews were sufficient to gather the relevant data and allow time to make short notes between interviews and were short enough so that the students did not lose interest.

At the start of the interview the students were told the purpose of the study and of their role within it. They were also informed that the interview would be taped, that no one other than the interviewer would listen to it and that they did not have to participate if they did not want to, which was rigidly adhered to. It is more likely that some students may choose not to participate in this part of the study as the experience is more personal than a questionnaire and some students may feel more self-conscious about being recorded. Only one student chose not to participate on the day, however, as the interviews were conducted during the school day and the overall mood of the interview was relaxed.

While several similar loose questions were asked to each group to maintain consistency, the questions needed to promote a wider discussion but put the students at ease within the situation. It was important that they did not feel like it was a test and that they would not be judged on the responses they gave. In order to facilitate this, a general chat, unrelated to the study, started the interview. Questions relating to their day generally or to their hobbies, for example, set the tone of the discussion and helped them feel valued. Once the students began to talk more openly the questions relevant to the study were asked. As shown in Appendix 6 the first of these questions simply asks the student why they felt the way they did about using CAD, whether this be positive or negative. As the interviewer is familiar with the tasks and has a positive experience with the use of CAD it is important that these views were not expressed and did not influence the discussion; however, the discussion needed to be prompted at times to provide more in-depth information. This question intended to determine the reasons some students enjoy using CAD and others don't. In particular, whether problems highlighted by the literature review, such as gender and technophobia, are relevant to these students. The second question asked the student if they felt working in pairs was beneficial to them. This question aimed to determine if they felt that CSCL, also identified in the literature review, would help them to enjoy and/or use CAD more effectively. The third question concerned the use of characters to show the students how to use the program, allowing them to work more independently and at their own pace. In order to explain this question an example (Appendix 6) was available to show the students which they could discuss. Further questions related to creativity, the first of which asked the students what they thought creativity was. This was intended to set the criteria and help them to answer the next question which was, 'do you think your work was creative?' In order to answer this question the students needed to have an understanding of what they were aiming for. A further aim of the question was to determine if students are not being creative because they don't know what is expected of them. Finally the students were asked what had helped or prevented them from being creative depending on their previous response. The students were also given the opportunity to add anything further that they wanted to.

When reporting on the findings for this study the taped discussion was transcribed by the researcher according to groups of responses. For example, if three of the group said they enjoyed making 3D shapes, then this was reported as one element along with any single responses, and any responses that were particularly animated were also highlighted. All responses were reported on through this method.

The results from this study were then used to develop an alternative method of learning CAD in the classroom as an intervention which was delivered in the following school year.

4.8.3 Creative ability

To determine the creative ability displayed by the students at the end of the period of study and to establish whether lack of creativity when using CAD is an issue, the work was assessed by the same experienced panel of three teachers that had assessed creativity in the pilot study. The levels in this study and subsequent studies were reduced from five levels to three levels as five levels had been difficult to manage and the experienced teachers on the panel believed that five levels had not provided any additional useful data than three levels would. The students' work was separated into three categories according to the following preset criteria:

Level 3 – Low creative ability shown. Design uses only basic shapes and doesn't vary from the example shown by the teacher in any significant way.

Level 2 – Some creative ability shown. Design shows some attempt at using more complex shapes and commands and differs somewhat from the example shown by the teacher.

Level 1 – Good creative ability shown. Design uses complex shapes and combinations of shapes that differ significantly from the example shown by the teacher.

The work of all the students who completed the period of study was assessed in this manner to ensure the widest possible sample. The results of this study were then compared to the responses given in the questionnaire in order to determine whether certain creative ability levels are more likely to give certain responses.

4.9 Study 3 – Comparison of student attitude and outcome of CAD learning following intervention

Two possibilities presented themselves when considering which year group should participate in the intervention study. By delivering the intervention to the same groups who were just starting in Year 8 a direct comparison could be made between their current and previous answers in order to investigate the effect of the intervention. One disadvantage of this was that the students may have had very set preconceived ideas about using CAD. The students would also be familiar with CAD work from the previous year, which may mean that students enjoy using CAD or find using it easier even without the introduction of an intervention. The alternative was that the study could be completed with the new Year 7 group. To use these groups the induction day event would have to be delivered in a manner that was as identical as possible to the one the current Year 8 students had attended the previous year. This would have the advantage that the results from the previous induction day study could be compared with the most recent one. A disadvantage was that there could be no direct comparison between teaching styles as they had not experienced both types of lesson. As the intervention could be delivered to both groups it was beneficial to include both groups in the intervention study. In this way a further comparison could be made between the groups' responses in addition to the effect of the intervention itself.

4.9.1 Induction day study

To understand how the intervention had affected the students' learning and creativity when using CAD it was necessary to have data about their opinions before using the program. The previous results gained from the Year 8 students were sufficient for that group; however, the new Year 7s would need to attend a similar induction day event as the previous year group. To maintain consistency the event was delivered by the same teacher as the year before in the same classroom. The event was again spread over two days and involved around 300 Year 6 students rotating between six activities each lasting 45 minutes. As it was not possible to know which students will experience the intervention when they begin studying in Year 7 all of the 300 students were involved. Again due to the size of the sample a questionnaire was the most appropriate method to collect a large amount of numerical data and also the only way to directly compare the results of this year group and the previous one. This maintained consistency with the original study. A significant change from the pilot study was that the questionnaire did not need to include questions that had already been proven to be irrelevant to the study and was therefore identical to the questionnaire used at the end of the pilot study instead.

The students needed to provide their full name on the questionnaire in order to manage the data: from this point as before data was written using initials only.

The first question asked the students to indicate on a five-point Likert scale how hard they had found *ProDesktop* to use. The second question asked the students to indicate on a five-point Likert scale how much they had enjoyed using *ProDesktop*. The final question asked the students to explain why they thought they had answered the questions the way that they had. The purpose of this is to make sure the students completed the questionnaire correctly, as students often get confused and select the wrong end of the scale. The answer to this question may also provide a more detailed insight into the reason the student feels the way they do, which could be used for selecting a sample or to help direct questions during an interview.

4.9.2 The intervention

The design of the intervention is intended to take into account many of the aspects revealed by the research programme to date. These included:

- Known ways that students can be helped to be creative in the classroom as revealed in the literature review.
- Ways highlighted by the students during interview that they believe will help them enjoy using CAD more.
- A strategic knowledge approach to using CAD rather than command knowledge which can be accessed via help sheets or video clips instead.

Once both Year 7 and 8 students had begun studying in the 2009/2010 school year the students followed the same carousel of activities as the previous year groups at Key Stage 3. This involved three 50-minute lessons each week for a period of six weeks. To maintain consistency at this stage the students were taught in the same room that had been used for the previous studies and were taught by the same teacher. This study included around

150 of the Year 7 students and 50 Year 8 students. Not all of the Year 8 students had experienced CAD in their Year 7 lessons depending on their timetable and therefore this data was included with the Year 7 data. At the end of this period of study the students repeated a similar questionnaire to the one given to them at the induction day events. This questionnaire included three additional questions. These questions were open questions that the students could answer in more detail. The intention of this was that a wider understanding could be obtained quickly. A disadvantage is that the results could not be transferred into numerical data and therefore could not be easily compared, although a general positive or negative response was expected to all three questions which could be loosely grouped and used for more in-depth interviews at a later date.

The first question asked the students how they felt about working in pairs. This question intended to highlight how the students felt about CSCL and whether they felt it was a benefit to learning CAD. CSCL has been seen as a good method of assisting students to carry out computer-related tasks in previous research and it was relevant to establish whether students felt that it could also be advantageous when learning CAD. The second additional question asked the students if they believed using video clips helped when learning CAD. The intention of this question was to find out whether they believed that being able to access information for themselves and at their own pace was a benefit to them when learning CAD. The third question asked the students whether they believed the idea of game play and competition helped them to learn CAD. The intention of this question was to establish whether the students liked the idea of learning through a game and also if the element of competition was an incentive for them to put more effort into their work or if it discouraged them at all.

4.9.3 Semi-structured interviews

In order to gain more detailed responses from the students involved in the study those giving the most extreme responses in the questionnaire were asked to attend a short interview. To maintain consistency the setting and teacher for these remained the same as for the interviews previously held as shown in Appendix 6. The students were asked to attend in small groups of five or six for the same reasons as previously given and as before the interviews took place during school time and refreshments were given. The groups targeted for interview were:

Year 7

Group 1 – Significant increase in enjoyment

Group 2 – Significant decrease in enjoyment

Group 3 – Significant decrease in enjoyment

Group 4 – Significant increase in enjoyment

Group 5 – Significant increase in enjoyment

Year 8

Group 6 – Change in attitude noted through observation. The report of the findings for this group will take more of a case study approach as there are less students and more is known about the students and their work.

Again the students were informed of the purpose of the study and that the interviews were being recorded at the start of the interview. The students were also given the opportunity to opt out of the interview as before.

To relax the students the questions at the beginning of the interview took the form of general chat in a similar way to the previous interviews before moving on to the relevant questions. These questions were loosely formed so that the students could be open and the interviewer could respond to the answers as discussions occurred. The first of these questions was 'why did you feel the way you did about using CAD?' The intention of this question was to determine whether issues highlighted in the first set of interviews had been addressed by the intervention or whether any new concerns had arisen because of it. The second question asked the students to expand on the answers given in the questionnaire relating to working in pairs to gain further insight into whether CSCL had been successful in addressing any issues relating to learning CAD. The third question asked the student to expand on the answers given in the questionnaire relating to using video clips to determine whether this had allowed pupils to work more independently at their own pace or not and if this had helped them when learning CAD. The fourth question asked the students to expand on the answers they had given in the questionnaire relating to the use of game play and competition when learning CAD. The intention of this was to determine whether they believed this had helped them when learning CAD. The students were then asked what they believed creativity was and whether they felt that their work had been creative. The purpose of this was the same as in the first set of interviews in that it is necessary to find out if students know what creativity is and if they know what is being asked of them in lessons. Finally the students were given the opportunity to add anything further that they wished.

The student responses for this study were grouped as they had been in the previous study. If a majority of the students had the same response or any student had a more extreme reaction then this was reported.

4.9.4 Creative ability

The most relevant data gathered from the research at this time was the students' own work as it was the creativity and ability displayed in this work that was most relevant to the study. As before the work was placed into three categories by the same panel of three teachers according to the same preset criteria as before. Even if there is no change in student attitude to using CAD but the students show an increased level of creativity the intervention would be considered successful.

To determine the creative ability displayed by the students, at the end of the period of study the work was assessed by the same experienced panel of three teachers. The work was separated into three categories according to preset criteria:

Level 3 – Low creative ability shown. Design uses only basic shapes and doesn't vary from the example shown by the teacher in any significant way.

Level 2 – Some creative ability shown. Design shows some attempt at using more complex shapes and commands and differs somewhat from the example shown by the teacher.

Level 1 – Good creative ability shown. Design uses complex shapes and combinations of shapes that differ significantly from the example shown by the teacher.

The work of all the students who completed the period of study was assessed in this manner. The results of this part of the study were then compared to the answers the students had given in the questionnaires. The purpose of this was to determine whether certain responses to the questionnaire had any relationship to their creative ability level. The work from the Year 8 students was also compared to work they had completed in Year 7 in order to establish whether any improvement was evident. Although this was relevant to the study it must also be considered that any improvement was likely to be general improvement and due as much to experience and maturity as it was to the intervention.

4.10 Study 4A – Examining student and teacher attitude and outcome when intervention is delivered by an alternative *teacher*

To further examine whether the intervention had had an effect on the pupils learning CAD and on their ability to be creative when using it, the intervention study was also delivered to a group by a different teacher. The intention of this was to consider whether the teacher influences the outcome of the study or if the results remain the same as in the previous study regardless of the teacher involved. The study took place in the same school and in the same teaching room. The teacher involved in the study had taught in the school for several years and was experienced in teaching 3D SMCAD but had less experience than the teacher in the previous studies. One advantage of this was that teacher view can then be considered as the effect of instructor knowledge and confidence in student attitude and performance, as highlighted in the literature review (Pektas and Erkip, 2006)

4.10.1 The sample

This study involved a smaller number of students as it was testing the rigidity of the theory rather than a new theory and therefore needed to be more focused. The sample for this study included a class of 25 students of mixed ability and mixed gender, thereby ensuring that all students were represented in the sample. In a similar manner to the introduction of the previous studies the students were shown the various types of CAD programs and then asked to complete a questionnaire to establish the students expected enjoyment and difficulty when using CAD. Unlike the previous studies the introduction was delivered by a different teacher at the beginning of the program of study instead of at the induction day event. A disadvantage to this approach was that the students did not have any delay between introduction and starting the program of study; therefore the emotions documented in the questionnaire were fresh in their mind and may have had a stronger effect when starting to learn CAD. The students may have felt very differently once they started studying at the school rather than at the induction day event. It is possible that the students may have felt more confident or at ease within the situation. To reduce the effect of this, the study took place at the beginning of the school year before the students had become established in their environment. A further disadvantage was that the teacher may have delivered the introduction in a different way which may have affected student opinion when completing the questionnaire. An advantage of this approach is that the students would be familiar with the teacher involved in the study, thus establishing a relationship between teacher and students. An important advantage, however, is that the theory and student attitude can be assessed considering different teachers' delivery of the intervention. The intention is that the intervention should improve students' creativity when using 3D SMCAD regardless of the teacher involved in the delivery and this study considers this theory.

4.10.2 Questionnaire

To maintain as much consistency as possible the questionnaire given at the beginning of the program of study was the same as the one given at the induction day event. The students needed to provide their full name on the questionnaire in order to manage the data: from this point, as before, data was written using initials only.

The first question asked the students to indicate on a five-point Likert scale how hard they had found *ProDesktop* to use. The second question asked the students to indicate on a five-point Likert scale how much they had enjoyed using *ProDesktop*. The final question asked the students to explain why they thought they had answered the questions the way that they had.

4.10.3 The intervention

The intervention was then delivered over the period of a six-week course of study consisting of two 50-minute lessons per week. This is different to previous studies as there had been a change in the structure of lessons timetabled to Design and Technology. At the end of this the students were asked to complete the questionnaire given to the students at the end of Study 3. This included the same additional questions, that is, asking the students how they felt about working in pairs, if they believed using video clips helped when learning CAD and whether they believed the idea of game play and competition helped them to learn CAD.

4.10.4 Creative ability

Again the most relevant data gathered from the research at this time was the students' own work as it was the creativity and ability displayed in this work that was most relevant to the study. As before the work was placed into three categories by the same panel of three teachers according to the same criteria as before. The results from this were then compared to those recorded at the end of Study 3 to assess whether the delivery of the intervention by an alternative teacher had any effect on the creative ability of the students when using 3D SMCAD.

This was completed in the same way as in the previous studies in that the work was assessed by the same experienced panel of three teachers as in the previous studies and the work was separated into three categories according to preset criteria. These categories were:

Level 3 – Low creative ability shown. Design uses only basic shapes and doesn't vary from the example shown by the teacher in any significant way.

Level 2 – Some creative ability shown. Design shows some attempt at using more complex shapes and commands and differs somewhat from the example shown by the teacher.

Level 1 – Good creative ability shown. Design uses complex shapes and combinations of shapes that differ significantly from the example shown by the teacher.

4.10.5 Teacher view

An additional aspect to this study was a report written by the teacher loosely in the form of a diary which documents their observations and experiences of using the intervention with their students. Little direction for this report was given to the teacher by the researcher in order to allow as much freedom as possible in its content. The report includes a summary of the teacher's experiences at the end of each lesson. Finally the teacher was asked to provide a conclusion on how they believed the intervention affected the students' work and the outcome of their work.

When reporting on the findings from the teachers' diaries, which can be found in Appendices 12 and 13, all data relating to the relevant aspects of the teaching method and the students' learning, such as the teaching value of paired learning, the game, creative outcome and any particular difficulties the teacher experienced, were summarised and included in the findings. One of the central theories of this teaching method is that paired learning may be a valuable technique in helping students to learn complex CAD software; therefore it is important that any positive experiences and learning outcomes or any problems observed with the paired learning during lessons, such as one student doing all of the work or arguments that hinder the work outcome or learning, are included in the teacher diary findings. Particular problems involving the technology itself were also included, as this is an aspect that teachers often experience and can affect the overall outcome of the work if not resolved quickly as well as affecting the teacher and student motivation.

4.11 Study 4B – Examining student and teacher attitude and outcome when intervention is delivered in an alternative *school*

To further test the effect of the intervention, the previous study was repeated in a different school with a different teacher. The school used for the study was also a semi-rural school with 1850 students on roll. The Design and Technology department was of a similar size with similar facilities to the one used in previous studies. The head of department had expressed concerns as to both the students learning of 3D SMCAD and staff confidence in teaching the program. By repeating the study in these settings it was possible to gain an insight into the effect of the study on students and staff in an alternative school as well as whether the intervention was able to be delivered by less experienced staff.

Apart from the setting the study took place in, all other aspects were identical to Studies 3 and 4A. The intervention was delivered to a single group of 22 of mixed ability and gender over a six-week period involving two one-hour lessons. The study started as soon as the students were enrolled at the school so that they would be at a similar stage and state of mind as the students in Studies 3 and 4A. The teacher began the programme of study by introducing the types of CAD and asking the students to complete the same questionnaire that was used at the beginning of Studies 3 and 4A. The teacher then delivered the intervention, at the end of which the students were asked to complete the same questionnaire that was used at the end of Studies 3 and 4A. Again, due to the size of the sample all of the students in the group were interviewed but this time by the teacher of the class in a setting that was familiar to them. The setting for the semi-structured interviews was their own school in order to maintain a relaxed atmosphere. By using a teacher who was familiar to the group, the students were more likely to answer the questions fully and honestly. As in the previous studies drinks and biscuits were provided so as to make the experience feel like a treat rather than a normal lesson. Informal questions at the start of the interviews were asked to further relax the students as before. The questions then asked in the interviews were the same as those used in the semi-structured interviews in Study 4 to gain a further insight into the reasons for their answers. The work of the students was then assessed for creativity by the same panel using the same criteria as in the previous studies to maintain consistency.

Finally, as in Study 4A, the teacher was then asked to write a diary with minimal direction. Again the teacher included a summary of their experiences at the end of each lesson. At the end of the report the teacher then provided a conclusion on how they believed the intervention affected the students' work and its outcome. At the end of this report a short interview between the teacher and the researcher was necessary to clarify any points that were not fully understood or that needed expanding upon.

4.12 Endnote to Chapter 4

The iterative nature of the action research approach has ensured that the conclusions made during the studies are both reliable and valid, as data has been checked against subsequent groups and in groups in other schools. By taking this approach, a number of methods could be used providing a range of both qualitative and quantitative data from which to draw conclusions and to provide information to focus later studies. A summary of research methods used in the studies is shown in Table 4.1.

Table 4.1 Summary of research methods used in studies

	Pilot study	Study 2	Study 3	Study 4A	Study 4B
Pre-task questionnaire	/		/	/	/
Post-task questionnaire		/	/	/	/
Spatial awareness test	/				
Creativity assessment	/	/	/	/	/
Semi-structured interviews		/	/		
Teacher diaries				/	/

Chapter 5 Study 2: Examining student attitudes to existing teaching of CAD programs

5.1 Introduction

Chapter 3 explored some problems highlighted by the literature review concerning the learning of 3D SMCAD in the classroom today. This chapter seeks to further this exploration by focusing on key issues identified in Chapters 2 and 3 through the reporting and monitoring of student attitude and opinion through a six-week course of study. This notes changes in attitude following actual use of the program. Following the six-week course of study the students were interviewed to gain a deeper understanding of the strategies they believed would help them to be more creative in their CAD modelling. The results of this study were then used to develop an intervention as an alternative method of teaching 3D SMCAD. The results of the intervention study are reported on in Study 2.

5.2 Methods

Table 5.1 Summary of research methods used in Study 2

	Study 2
Pre-task questionnaire	
Post-task questionnaire	/
Spatial awareness test	
Creativity assessment	/
Semi-structured interviews	/
Teacher diaries	

An evaluation of the methods chosen for the research were presented in Chapter 4. However, this section begins with a review of the particular methods selected to aid an understanding of the study. This study followed the same students who participated in the pilot study through a six- week programme of study. At the end of this study the students were asked to complete a similar questionnaire to that which they had completed previously. The intention of this was to compare the results of the two questionnaires to examine whether students' attitudes changed either positively or negatively from their anticipated level of enjoyment and difficulty once they had actually used the 3D SMCAD program. The questions omitted from the questionnaires had been found in the previous study to be least relevant to students today. Those students whose attitudes had changed significantly were then asked to attend interviews in small groups. This allowed the students an opportunity to express their views in more depth. It also allowed pupils to suggest ways in which they believed learning could be creative when using CAD and how CAD could be made more enjoyable and easier to use. At the start of the interview students were informed that any taped responses would not be heard by anyone else and therefore the students involved in this study are referred to by their initials to further preserve this confidentiality

5.3 The programme of study

The programme of study which the students completed follows the traditional method of teaching CAD. The course involved three 50-minute lessons a week for a period of six weeks. In all of these lessons the students worked as individuals rather than in pairs, although, naturally, the students often tried to help each other. This action by the students was neither encouraged nor discouraged providing it did not interfere with their own work.

Lesson 1

The first lesson presented the programme of study and introduced the students to the tools and vocabulary that they would be using in later lessons. This was considered important as many of the words used within the programme, such as extrude and loft, were new to them. To further enforce the visual image of these words, props (Chinese lanterns and blocks) were used to demonstrate the features. The concept of 2D and 3D objects was also explained at this stage in order to make navigating the toolbars easier in later lessons.

Lesson 2

In this lesson the students followed the traditional pattern of learning CAD. To achieve this, the teacher used a projector to show the students how to complete a 2D shape, in the first instance a square, and extrude it. They then followed the instructions in a step-by-step manner as the teacher gave them. The teacher then showed the students a more complicated freeform shape, thereby introducing the concept of whole shapes with no crossing lines or gaps. The students then followed the instructions in the same way as before. At the end of the lesson the students wrote out the instructions for this feature so that they could follow them later. The disadvantage of this method of learning is that all students need to remain quiet during the instructions. This is difficult for most students as they like to discuss what they are doing, especially if they are finding the work difficult. The students also need to work at the same pace, which creates difficulties, as some students gain an understanding of the basic concepts far more easily than others. These students often appear to get bored and chat or misbehave. A further problem is that students who experience problems they are unable to solve for themselves often sit for several minutes with their hand up waiting for help until a teacher is able to get to them.

Lesson 3

This lesson centred on teaching the students to create new workplanes and new sketches in order to work on the various surfaces of their 3D shapes. From observation this is the most common reason for their CAD models to fail, as they often struggle to understand which workplane they are actually on or they forget to add a new sketch once they have added a new workplane or when they want to complete a new feature. For this reason some time was spent on this set of commands. To teach this the students were shown a box, and paper and tracing paper were used to demonstrate creating and selecting the sketches and workplanes. The students were then shown via the projector how to create the workplanes in the same step-by-step manner as in the previous lesson while following the instructions.

Lesson 4

This lesson aimed to teach the students the more advanced commands of creating offset workplanes and lofting through profiles. This involved them creating a series of three offset workplanes and sketches and drawing a 2D design on each workplane. The 2D shapes were then connected by using the loft feature. To begin the lesson the teacher explained the concept of lofting by describing a tent frame as a series of 2D shapes and then applying the tent canvas to create the final 3D shape. In the same traditional manner the teacher then used a projector to show them step by step how to complete the feature, while the students followed. All of the students were able to complete a model using the feature. Following this they wrote down the instructions in order to help them complete a model using the loft feature on their own. Most students were able to create a successful model but around 50% needed the help of the teacher at some point in the process to problem-solve or explain the next step.

Lesson 5

This lesson introduced the idea of revolving a profile around an axis. To demonstrate this, a Chinese lantern in the shape of a bell was used. The half-bell shape was shown as the profile and a red line as the axis. Common mistakes were demonstrated, such as not creating a straight line for the profile to revolve around or creating a shape that would revolve into itself causing the model to fail. Following this demonstration, in the same traditional manner the teacher used the projector to show them step by step how to complete the feature, while the students followed. The students then wrote down the instructions in order to help them complete a model on their own. Again most students were able to complete a successful model and around 50% needed help from the teacher at some point to problem-solve or explain the next step.

Lesson 6

Often students want to work on round surfaces. This involves creating offset workplanes and projecting onto the surface. To demonstrate this feature the teacher used a round building block and paper. The students were then shown how to avoid common mistakes such as the projection missing the model because the 2D shape was drawn outside the 3D model. Following this demonstration, in the same traditional manner the teacher used the projector to show them step by step how to complete the feature, while the students followed. The students then wrote down the instructions in order to help them complete a model on their own. Again most students were able to complete a successful model and around 60% needed help from the teacher at some point to problem solve or explain the next step.

Lesson 7

One feature that proved popular with young students was being able to create a helix. The sweep profile along helix command is a reasonably simple feature to complete as it is similar to the revolve command. To begin the lesson the students were shown the common mistakes that occur such as not creating a new sketch for the axis and making the profile too big or close to the axis so that it hits itself when it is tried. The teacher then followed this demonstration with the same traditional manner of using the projector to show them step by step how to complete the feature, while the students followed. The students then wrote down the instructions in order to help them complete a model on their own. Again most students were able to complete a successful model and around 60% needed help from the teacher at some point to problem solve or explain the next step.

Lesson 8

Often students struggle to combine features in the same design and therefore this lesson centred on showing the students how to assemble components. To begin the lesson the idea of combining components was demonstrated by using different shaped building blocks. The students were then again shown how to avoid common mistakes. In this instance the main problems involved the students not maintaining consistent scale in their various designs and the orientation in which the components come into the design. Following this demonstration, in the same traditional manner the teacher used the projector to show them step by step how to complete the feature, while the students followed. This mainly involved demonstrating how to create their designs in the correct sizes and how to rotate their components. The students then wrote down the instructions in order to help them complete a model on their own. Again most students were able to complete a successful model and around 30% needed help from the teacher at some point to problem-solve or explain the next step, however often the components were brought into the design in different scales. This does not cause the model to fail but may change the students' design in later exercises.

Lesson 9

Most students appear to enjoy adding colour and materials to their designs and the command is quite easy to apply; therefore little help or instruction was needed during this lesson. The process of rendering is completed in a separate part of the program, however, and the lesson began by the teacher explaining to the students about the different file types, as this can often be confusing for students when they try to save and retrieve their designs. Although very few problems occur when students are rendering their designs, often students forget to update them. This stops the material and colour being applied to their model and this action is reinforced before and during demonstrating the command. Following this explanation the rendering action was demonstrated in the same traditional manner by using the projector to show the students step by step how to complete the feature, while the students followed. The students then wrote down the instructions in order to help them complete a model on their own. Again most students were able to complete a successful model and around 10% needed help from the teacher at some point to problem-solve or explain the next step.

Lesson 10

To further reinforce the file types that form the 3D SMCAD program the students were shown how to create engineering drawings. To begin this lesson the students were shown the features of both third-angle projection drawings and isometric, including adding dimensions. Following this demonstration, in the same traditional command-led pattern the teacher used the projector to show them step by step how to complete the feature, while the students followed. The students then wrote down the instructions in order to help them complete a model on their own. Again most students were able to complete a successful model and around 40% needed help from the teacher at some point; in this instance most of the problems involved adding dimensions to the drawing.

Lesson 11

Students frequently forget how to complete the basic commands which are essential to creating a successful model. This lesson recapped the basic commands of drawing 2D shapes before extruding them and working on the new surface. The demonstration began by completing the same block design as in lesson 3 but then continued by showing how these commands could be combined to create a basic robot shape which would form the basis of the rest of the lessons in the scheme of work. A robot was chosen for this project because when asked what they would like to design, both boys and girls chose to make a robot. A criticism of asking the students to create a robot is that robots are often depicted in a similar form in media such as books, cartoons and films. Consequently this may have restricted the students' ability or desire to create something too far removed from this stereotypical image; in other words it may have had an impact on their opportunities for creativity. The students finished the lesson by using the notes that they had previously written in order to refresh their memories of the basic commands.

Lesson 12

To provide a comparison between the hand-drawn designs and those drawn using the computer, the students were asked to spend this lesson sketching a design for a robot. They were asked before starting the task to think of different robots they were aware of and what their chosen robot might be able to do. These were written on the board to try and help students to think differently from the standard image. Once they began their designs the students were able to talk about what they wanted their robot to look like in detail and appeared excited by their ideas.

Lessons 13–17

In these five lessons the students used the notes that they had previously written to help them design their robots using 3D SMCAD. By allowing five lessons the students were able to restart their designs in order to improve them if they wished. Often the designs only included the basic features of drawing 2D designs and extruding them and working on a new surface. Initially the lesson began with a demonstration of these basic features by the teacher. During the first few lessons many of the students required a considerable amount of help from the teacher; this had the disadvantage that often the students were waiting for help to solve problems rather than completing work. In the later lessons the students were reluctant to try the more difficult features and often those that did try these features wanted to be helped by the teacher rather than helping themselves by reading their own instructions.

Lesson 18

At the end of this period of study the student completed a questionnaire similar to that which they had completed during the induction day event. Any questions found to be irrelevant to this research in the pilot study were omitted. In all other aspects the questionnaire remained the same in style and wording to maintain consistency. The students also completed an evaluation of their work in the same way as they would have done previously in this programme of study. The intention of the evaluation was to encourage the students to critically consider their own work and the work of others. The evaluation asked the students to write what they liked and didn't like about their own work and then asked others what their opinion of the work was before suggesting ways in which it could be improved. A concern with this process is that students often prefer to use one-word answers or fail to be descriptive in their evaluation and some time needs to be spent by the teacher encouraging the students to fully answer the questions. This evaluation was extremely useful for the purposes of the study as the results could be compared to the answers given in the questionnaire and a deeper understanding of the students' answers could be examined.

5.4 Findings

From the questionnaires 15% of students chose number 1 when showing how hard they had found *ProDesktop* to use, indicating that they thought it was easy to learn. Number 2 was chosen by 25%, 34% chose number 3, 16% chose number 4 and 10% chose number 5, indicating that they had found it hard to use. When compared to the answers the students gave in the first questionnaire in Study 1, 53% of students found *ProDesktop* easier to use than they had expected, 20% found it difficult to use and 28% of students found *ProDesktop* harder to use than they expected (see Table 5.2).

Table 5.2 Level of difficulty when using* ProDesktop *and a comparison with expected level of difficulty in pilot study

	Study 2
Easier to use	53%
As difficult	20%
Harder to use	28%

	Study 2
1 – easy	15%
2	25%
3	34%
4	16%
5 – difficult	10%

Some 34% of students chose number 1 for enjoyment, indicating that they had enjoyed using the program, 23% chose number 2, 19% chose number 3, 17% chose number 4 and 7% chose number 5, indicating that they hadn't enjoyed using the program. When compared to the answers given by the students in the first questionnaire in Study 1, 28% of students found *ProDesktop* more enjoyable to use than they had expected, 37.5% found it as enjoyable and 34.5% found it less enjoyable than they had expected (see Table 5.3).

Of those students who had enjoyed using *ProDesktop* more than they had expected, 29% found it more difficult to use, 12% found it as difficult and 61% found it easier to use. Those who had indicated that their enjoyment had stayed the same accounted for 18% who found *ProDesktop* more difficult to use than expected, 24% who found the difficulty level the same and 58% who found it easier to use than expected. Finally, of those whose enjoyment had decreased, 36% found *ProDesktop* more difficult to use than expected, 20% found it as difficult and 44% found it easier to use than expected (see Table 5.4).

Table 5.3 Level of enjoyment when using* ProDesktop *and a comparison with expected level of enjoyment in pilot study

	Study 2
Enjoyed more	28%
Enjoyed the same	37.5%
Enjoyed less	34.5%

	Study 2
1 – enjoyed	34%
2	23%
3	19%
4	17%
5 – did not enjoy	7%

Table 5.4 Comparison of enjoyment and difficulty

	More difficult to use	As difficult to use	Easier to use
Enjoyed more	29%	12%	61%
Enjoyed the same	18%	24%	58%
Enjoyed less	36%	20%	44%

From comparing the results of the two questionnaires six groups of students were selected to be interviewed regarding their opinions and why they believed they felt the way that they did when using *ProDesktop*. All students who had experienced a change in attitude or extreme views regarding using the CAD software were invited to take part in this study; however, on the day of the interviews some students were away.

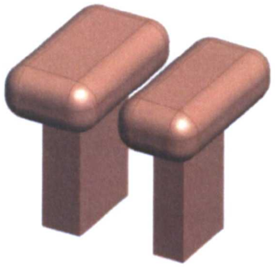
Group 1 – significant increase in enjoyment when using *ProDesktop*

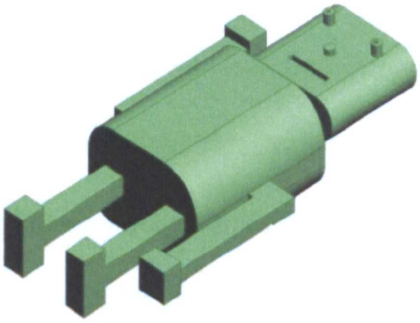
3 participants: all males – JC, TW, MR

The group had shown on the first questionnaire that they had thought that the program would be hard to use and also that they wouldn't enjoy using it; however, they had found that their enjoyment was significantly higher than they had expected. All the students indicated that the reason their enjoyment had increased was that they had actually found it easier to use than they had thought it would be. JC also stated that he had enjoyed it because of the 3D aspect of the program, which he said had made him proud of his work as it looked better than the 2D designs he had made previously. MR said he was keen to use the program as it was the sort of thing architects use and he wanted to be an architect when he left school. JC thought it would be a good idea to have a visit to a company which used the program a lot as it would show what you could do and what you could work towards. TW said he also enjoyed the program because of the robot project they did and he enjoyed solving problems. The students all agreed that the robot theme for the project was good because they could make it simple or more complicated as they got more confident. The students then said, however, that it would be better if they were given time later in the project to make something of their own choosing. They all agreed that this would be difficult, though, as they would need to know exactly what they were doing.

MR said he had thought that the wall displays had put him off as it looked too complicated with lots of lines and instructions with the pictures. All of the students said they hated writing out the instructions but agreed that often people don't read them otherwise. The students were then asked to suggest alternatives that would make the program more enjoyable. JC suggested that the instructions had more pictures in them and was then shown a book that could be used as a possible intervention. Overall the students liked it and thought it was a good idea even though initially they would spend less time on the computer. MR said that in the end they would spend more time on the computer as they would spend less time needing help. TW suggested that the book should include some challenges that they could work through at their own pace. All said the characters illustrated in the book were okay because they added interest and made the instructions seem more fun. MR then said that a wizard theme would be good, as it would seem like a game that you could play. The wizard would introduce the program and then tell you to make him a mansion and you could follow the instructions he gave you to do this. All then agreed with this and began discussing possible scenarios and things the wizard could show you how to make. One suggestion developed between the participants was that short video clips could be included as part of a video game that would allow you to do different things as different points.

Finally the students were asked what they thought creativity was and they all said it involved some sort of doing or making that used your imagination. JC said that it was making something others wouldn't have thought of. All three of them when asked said that they didn't think they had made a creative-looking robot as they felt they had only just worked out how to use the program when the project ended. They all also said that not knowing how to do the things they had wanted to do had stopped them making the robot more creative (see Figure 5.1).





MR's robot JC's robot TW failed to save his

Figure 5.1 Group 1 students' work following traditional teaching method

Group 2 – Expected the program to be enjoyable to use then found it to be enjoyable

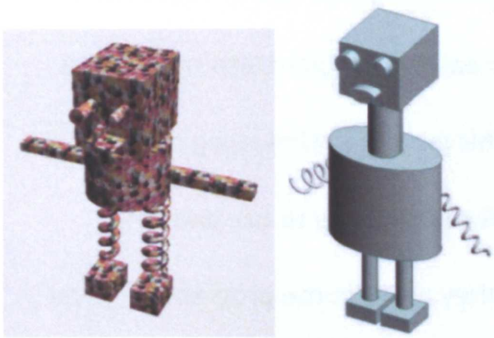
4 participants: all females – RL, LM, JP, EL

This group had shown on the first questionnaire that they had expected to enjoy using *ProDesktop* and on the second questionnaire had indicated that they had actually enjoyed using the program.

The reasons this group gave as to why they had enjoyed using the program were quite similar to the first group in that they felt that it may help with future careers, that it was different from other programs they had experienced and that you got to play around with shapes, which was interesting. Although EL had indicated that she expected to enjoy using *ProDesktop* initially, she had found it hard and boring but felt it had got better as she had learned to use it more effectively. RL also indicated that she thought she would enjoy using *ProDesktop* but said in interview that 'computers aren't my cup of tea but you get used to it'. This group's opinion of the instructions they had been given were different from the first in that they had found the instructions useful and easy to follow. The first group had said that the instructions didn't show the icons clearly enough but this group said that the small screenshots showing what you had to do were clear and had helped them work independently at their own pace. EL added that she had felt proud of herself when she had got it right.

In a discussion regarding how the project could be made better RL said she would prefer more choice of project and that levels could be introduced so that the better you did the higher level you got. When asked how she thought others might feel if they couldn't get very high on the levels, she said some might feel disappointed but it might make them try harder. LM agreed, saying that more competition would be good.

Discussion regarding creativity again showed that the students had an understanding of the term creativity by describing it as making stuff that no one has thought of before', 'different things' and 'things that use inspiration'. When asked if they thought their robots were creative, they limited conversation to colour and materials but felt that they had been creative. Again the reasons for not being more creative centred on not being able to make more complex shapes (see Figure 5.2).



LM's robot RL's robot

Figure 5.2 Group 2 students' work following traditional teaching method

Both of the robots in Figure 5.2 show good ability as the students had included more than one feature but limited creativity. JP and EL failed to save their design.

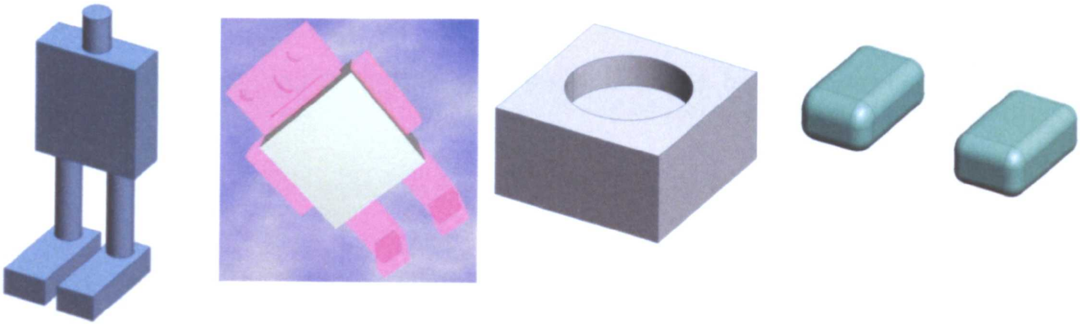
Group 3 – always expected to enjoy and then enjoyed using *ProDesktop*

4 participants: 2 males and 2 females – CM (f), SP (f), BM (m), RN (m)

This group had shown on the first questionnaire that they had expected to enjoy using *ProDesktop* and on the second questionnaire had indicated that they had actually enjoyed using the program.

Overall this group felt that *ProDesktop* had been enjoyable to use because it was easy and different to other programs they use. They felt it was easy to put 3D shapes together and that the 3D aspect of the program added to their interest. They felt that *ProDesktop* could be more enjoyable if they could design anything they wanted to or have more challenging projects, including the opportunity to have more time and freedom generally in the project. When asked how they thought this might affect students who weren't as confident or good at the program, they said that they could work in pairs or groups to sort the problems out. If they got stuck they could break the problem into smaller bits and possibly simplify the design if they needed to. This group felt that using characters in the instructions would help make the instructions more enjoyable to use and help students to become more confident. A further way they thought the program could be made more easy to use was if they spent more time looking at what workplanes and different features are before they start on the computer. They also felt that designing on paper before trying to design on the computer might help students to work out how to make their design on the computer.

Although all the students saved their designs they had a varied level of success and still lacked creativity as they mimiced, to some degree, the designs they were shown (see Figure 5.3)



RN'srobot SP's robot CM's robot BM's robot

Figure 5.3 Group 3 students' work following traditional teaching method

Group 4 – always expected to hate using *ProDesktop*

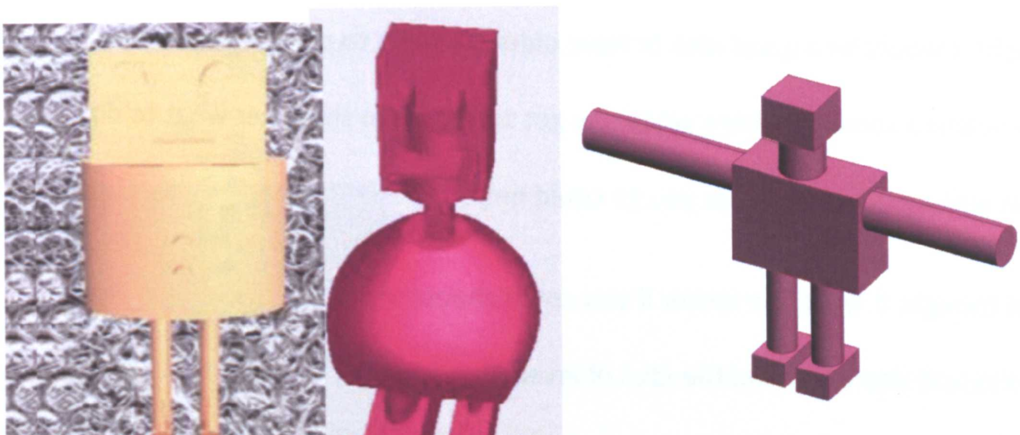
4 participants: 2 males and 2 females – CB (f), BG (f), LB(m), AC(m)

This group had shown on the first questionnaire that they had expected not to enjoy using *ProDesktop* and on the second questionnaire had indicated that they had actually not enjoyed using the program.

This group stated that the reasons they had not liked using *ProDesktop* was because it was hard and very confusing to use. CB said that they would prefer to have a choice when using the program as to what they make and that he would make a car. BG added to this, saying it would be better if you could make something you could use with the program. AC said there was too much reading involved and it would be better to just get on with it. AC continued by saying that competition would be a good idea but LB disagreed, saying that the competition would put her off. CB said that working in pairs or groups would help but agreed that some students may use this as an excuse not to do any work. CB said that by giving different roles and then swapping roles it may stop students avoiding using the program. The group liked the idea of characters but wanted to be able to choose characters for themselves and also wanted better pictures in the instructions to make them easier to follow.

CB believed that simple things were not creative. LB thought that creativity involved using your imagination. All believed they had not been creative when making their designs on the computer as they had not had enough time and didn't feel they could use the program well enough.

LB shows some level of ability and some creativity as she has used more than one feature and has a applied aloft feature in a different way than was shown in the example given. AC failed to save their model (see Figure 5.4).



CB's robot LB's robot BG's robot

Figure 5.4 Group 4 students' work following traditional teaching method

Group 5 – always hated the idea of using *ProDesktop*

4 participants: 1 male and 3 females – HE (f), MG (f), GB (f), TD (m)

This group had shown on the first questionnaire that they had expected not to enjoy using *ProDesktop* and on the second questionnaire had said that they had not enjoyed using the program.

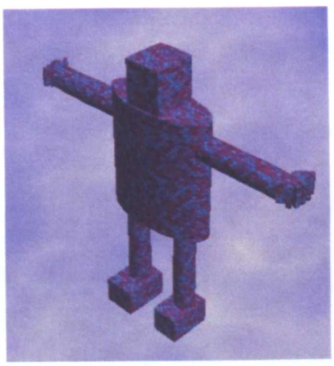
The reasons this group gave for not liking using *ProDesktop* was that there was too much information to take in and you couldn't remember it all. HE stated that it was too confusing and although the instructions were useful she often forgot to read them. She also said that she liked writing the instructions as it gave her a break from using the computer. GB disagreed strongly and said she wanted more computer time. TD couldn't see the point of learning CAD at all as he didn't see how it would help him after he left school. HE thought it would be a good idea to have older students to come in and help out because she wanted someone there when she got stuck and to show her what to do. MG thought that writing things down as you go could help.

GB said that she thought it would be better if you could choose what you made after first learning the basics and also discussed the idea of levels that you could progress through, as other groups had done. TD said the only thing that would make him enjoy the program more was if it was simplified. The group then discussed the problems that would occur with this because you wouldn't be able to do much with it.

This group gave the most dramatic action to the prototype characters intended for one possible intervention for delivery next year. TD shouted out, 'NICEEE!', then asked if they would be able to put the characters on their work before beginning to read the words in the speech bubbles out loud and then saying, 'cool'. HE thought it would be good to be able to add these as a treat for finishing the work. MG thought this would be good but wanted to choose the characters. When the idea of competition was introduced HE thought it would make the students rush their work. GB liked the idea of levels but not an outright competition as she didn't think she would do very well.

When creativity was discussed this group was unsure what it was, although GB eventually said 'making stuff' and MG said 'using what's in your head. GB didn't think her work had been creative as she felt she had only done what she had been told to do. MG and HE thought their work had been creative but referred only to colour and materials and being able to put their own patterns on their robot.

TD's robot shows a reasonable level of ability and some attempt at creativity. It varies from the others shown as he had tried to add fingers to it (see Figure 5.5). GB, HE and MG failed to save their designs.



TD's robot

Figure 5.5 Group 5 students' work following traditional teaching method

Group 6 – Significant change down

4 participants: 2 males and 2 females – AE (m), JL (m), PR (f), NS (f)

This group had shown on the first questionnaire that they had expected to enjoy using *ProDesktop* but had indicated on the second questionnaire that they had not enjoyed using it.

The general opinion of this group was that *ProDesktop* was too confusing and that they didn't get it. AE stated that it seemed simple but when you tried to use it, it was really hard. PR added to this, saying it wasn't just hard it was impossible. JL said that he had originally liked the idea as it looked like a challenge but had then found it too hard to do. NS believed that if you had a demo function like you have on a mobile phone to show you how to work the program, it would help. AE agreed and said you could play it every time you get stuck. PR stated that one of the things that had put her off was that when she looked at other students' computers they had got really good designs on them but that her's hadn't turned out as she had wanted it to, because she couldn't work it properly and had been really disappointed by this. NS said that she didn't like using computers other than for games and email and had therefore not liked anything to do with the program, although she wanted more time on the project to complete everything better. She thought that it would make it a bit easier if the class spent more time looking at what the layers (meaning workplanes) and sketches were before going on the computers, as this was really confusing. PR then said that she would prefer to make something they had chosen themselves. JL would have wanted to make a football and AE a skate park. Neither of the girls had any suggestions. As with previous groups the idea of the instructions becoming a game was discussed. This group liked the idea that each character represented a different level; PR also wanted to design their own characters. The idea of prizes for reaching certain stages was introduced by AE who suggested house points or king/queen for a lesson as a reward. The others liked the idea; however, JL felt that it would put you off if you couldn't do it. The group also suggested that you could have a certain number of lives or help choices, similar to a computer puzzle game, to help you.

When creativity was discussed with this group NS said that it was 'producing something from your imagination', although PR thought that involved the colour and EL believed being creative involved being able to make the shapes. None felt that they had been creative in the project work as they felt they hadn't had time to complete it properly and just followed the basic instructions.

Only AE from this group had saved a robot design and this displayed a very limited outcome (see Figure 5.6). This perhaps indicates that being unable to complete a model to their satisfaction led to a decrease in enjoyment.

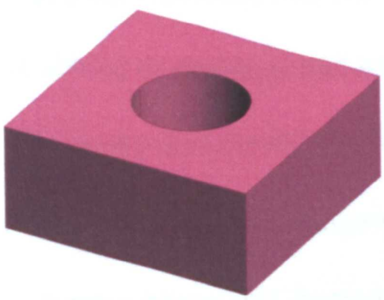


Figure 5.6 Group 6 students' work following traditional teaching method

When considering creative outcome, 10% achieved a level 1 by showing high levels of creativity, 25% achieved a level 2 by showing some creativity in their designs and 65% gained a level 3 by showing little or no creative outcome in their designs. This result indicates that the students displayed a limited level of creativity in their designs following this method of teaching.

5.5 Reflection on Study 2

Although only 15% of students stated that they found the program easy to use, a large percentage stated that they had found *ProDesktop* easier to use than they had expected. However, this is not evident in the students' work, which largely involves basic work, work that they chose not to save (indicating that they were not satisfied with the result) and incomplete work.

Of the 57% (34% level 1, 23% level 2) of students who stated that they had enjoyed using *ProDesktop* , 28% said that the program was more enjoyable to use than they had expected and a further 37.5% found it equally as enjoyable as they had previously expected. As many students had previously stated that they expected to enjoy using the program before using it this is a significant number and suggests that if they expect to enjoy using it then they probably will actually enjoy using it. The perception of difficulty when compared to enjoyment is also significant; of those who had experienced an increase in enjoyment, 61% had also found the program easier to use than they had expected. Of those who found that they enjoyed using the program as much as they expected, 58% also found the program easier to use than expected. This would suggest that if the student perceives the program as easy to use then they are likely to also enjoy using it more. Further investigation is necessary to validate these results, however, because of those who found that they enjoyed using the program less than they expected, 44% had also found the program easier to use than expected. One possible explanation for this result is that 69% of students in the first questionnaire had chosen level 1 or 2 on the Likert scale, which appears to be an unusually high percentage. This may have involved some expected movement once the study had actually begun and the initial excitement of the induction day was absent.

Interestingly the resulting answers from the semi-structured interviews were quite similar regardless of whether the students had enjoyed or not enjoyed using *ProDesktop*. Often the answers given linked to known methods of encouraging creativity. The students wanted to be able to problem-solve as they worked and they liked the idea of challenge. Several suggested the possibility of a set of levels that they could work through. Many of the students said they wanted to be able to work at their own pace and this seemed to be important to them. Most liked the idea of paired working and seemed to think that they would be able to work together to solve any difficulties that they had. One student suggested the idea of using video clips as this would enable them to see where the icons were, something they had found difficult to do on the help sheets they had used during the program of study. This would also be useful as it is possible to suit learning styles by including audio, pictorial and written instructions. Students would also be able to pause the clip allowing them to work at their own pace. Students may also be able to replay or rewind the clip, potentially allowing them to identify and solve their problems.

Although students were generally able to identify what personal creativity was, they were unable to identify it in their own work and little of their work was considered particularly creative by the panel of judges. From this it can be concluded that the current method of teaching *ProDesktop* is unsuccessful in allowing Key Stage 3 students to be creative, despite giving them an open task to finish the project.

All of the groups apart from Group 6 displayed a similar level of ability and creativity regardless of their opinion of how much or little they had enjoyed the task or how hard they had found using the program. All but one student out of Groups 5 and 6 had failed to save their work and both of these groups had said they didn't enjoy using CAD. This perhaps indicates that outcome has some effect on the students' attitude, although Group 4 displayed a good level of ability even though they said they hadn't enjoyed using CAD and Groups 1 to 3 had had varied outcomes; nevertheless they all stated that they had enjoyed using CAD. This may also indicate that the process rather than outcome affects the students' attitude to using CAD software. The results of this study will be compared to the results of the next study to examine whether this continues to occur.

The aim of this research was to compare two different methods of teaching CAD to Key Stage 3 students in order to determine if the students can be encouraged to be more creative when using the program. Initially the intervention was intended to take the form of a booklet involving characters who introduced tasks to students which the students could then work through at their own pace in pairs. The nature of action research involves the researcher responding to the results of their studies. In this case in response to the students' answers this intervention was adapted as it appeared to be more suited to the students. Rather than the student merely working through the tasks a scenario in the form of a game was created that also included levels. This allowed the students to have a more obvious indicator that they were progressing. To allow for the student to feel rewarded, points would be given, possibly involving a prize at the end. However, this could not only be for outcome, because this would not encourage the student to be creative and take risks but would focus on 'getting it right'. Therefore a two-level system of points would be included which also rewarded the student for trying something different. The most significant change would be that the game would include instructions in the form of video clips which would allow the student to have more freedom to work at their own pace, rewind and replay. A help section was also included in an attempt to help the students in trying to identify and solve issues that arise. The intention was not only to encourage the student to problem-solve but to free up the teacher so that rather than spending much of their time helping students to rectify their work they could encourage the student to develop their ideas through open questions and direction. In conjunction with paired working this supports the theory of computer-supported collaborative working.

The intervention encompasses many of points in the nine- and fourteen-point models to promote creativity recognised by Isaksen et al. (2001) and Hunter et al. (2007). These include the following:

1. Challenge and involvement – game scenario and inclusion of their own version of the designs within the task.
2. Freedom – ability to work at their own pace, revisit work and change their ideas as they work.
3. Trust and openness – no one correct answer plus reward for idea as well as outcome.
4. Idea time – working at their own pace allows the student time to develop ideas.
5. Playfulness and humour – game scenario allows for play.
6. Idea support – no wrong answer means all ideas are supported; however, not all ideas might be supported by the student's partner. By allowing both students to complete all tasks they will both be able to have their own ideas.
7. Debate – paired working allows for debate between them.

8. Risk-taking – attempting the tasks on an unknown and complicated software in itself involves risk-taking; trying to be creative adds to this.
9. Positive peer group – working in pairs and being awarded points (it should be relatively easy to gain low to mid-level points) should allow for positive peer group interaction.
10. Resources – access to the game and open access to the software
11. Autonomy – ability to be able to work at their own pace.
12. Reward – positive feedback from the teacher and peers in addition to points being awarded provides positive reward.

Chapter 6 Study 3: Comparison of student attitude and outcome of CAD learning following intervention

6.1 Introduction

Chapter 5 reported on student attitudes and the outcome of their work following a programme of study using traditional command-led techniques to learn 3D SMCAD. While many students had not changed their opinion from before they started the scheme of work, and therefore a large number enjoyed using the programme, their work showed limited creativity and often students were unable to complete or had not saved their work, often choosing to restart their design repeatedly. During interviews with the students whose attitudes had changed most significantly they suggested strategies that supported known methods for fostering creativity as identified in the literature review. These opinions were the same regardless of whether their attitudes had changed positively or negatively.

This chapter reports on the implementation and effects of an alternative method of teaching 3D SMCAD, created using student opinion, on the students' attitudes and their resulting work.

6.2 Methods

Table 6.1 Summary of research methods used in Study 3

	Study 3
Pre-task questionnaire	/
Post-task questionnaire	/
Spatial awareness test	
Creativity assessment	/
Semi-structured interviews	/
Teacher diaries	

For this study two options presented themselves. The alternative method of teaching CAD could be implemented in either the new Year 7 classes or in the new Year 8 classes which had previously been taught using the traditional method in Year 7. The advantage of the new Year 7 students experiencing the alternative method would remove the concern that the students preset opinions of the program might influence their final opinions. The Year 8 students experiencing the alternative method of teaching, however, would be able to provide a direct comparison in their experiences of the two different methods. Completing the study with both the Year 7 and 8 groups would provide the widest range of viewpoints and experiences and allow both the viewpoints and the work of the two year groups to be compared. A disadvantage of proceeding with both groups was that the size of the sample could be very large; however, not all of the students in Year 8 had experienced the programme of study in Year 7 and had access to the researcher as the teacher in the following year. Ultimately both year groups participated in the study; however, only one group of Year 8 students took part. To allow the results to be compared, the new Year 7 students completed a similar induction day event as the Year 8 students had prior to their enrolment in the school. Where possible this was identical in its delivery including the completion of the same questionnaire to maintain consistency. Both year groups then undertook the same programme of study.

6.3 The programme of study

As in the previous study both the Year 7 and Year 8 students followed a programme of study consisting of three 50-minute lessons for six weeks. In this study, however, the students experienced an alternative method of teaching developed by using a combination of their own ideas and the known methods of fostering creativity in students. Firstly, the students worked in pairs to allow for CSCL. The course also provided a scenario in the form of a game in which the students need to progress through various levels and included an element of competition which rewarded them not only for successful work but also for efforts of creative design regardless of outcome. To allow them to work at their own pace and be able to solve their own problems, video clips that the student could view were included in the programme of study. Written resources were also given, outlining common problems and how to solve them to allow greater autonomy. Reward was also given in the form of points to encourage students to solve their own problems and to encourage them to take risks by removing the need to 'get it right'.

Lesson 1

The first lesson introduced the students to the programme of study and the scenario. The scenario was presented as a game with an evil wizard capturing a village elder. This scenario was chosen as students being interviewed had suggested a wizard game and others had responded enthusiastically. The students had to act as villagers and were helped by a good witch who offered advice throughout the game on how to avoid common mistakes. The intention of having a strong female character goes some way towards increasing the visibility of women who have taken the lead in designing and using computer technology as suggested by the AAUW (2000). The first level of the game instructed the students to make a key which involved them using the 2D tools to create a whole shape and extrude it. In this part the witch showed them that crossing lines and gaps would make the model fail. One student in the pair then had control of a video clip that showed the students how to complete the key design; this student was able to pause and play the video as necessary in order to help their partner complete the model at their own pace. Around 30% of students needed help from the teacher to complete this; however, almost all of the students struggled on the same point. This mainly appeared to be due to the poor quality of the video clip as the students didn't see that a small line needed to be cropped. The students then switched places and repeated the task. During this task the students often seemed more confident and were able to produce more creative designs. This pattern followed throughout all of the tasks. Once the students had completed the key design they were awarded strength points for creating a successful model and courage points for attempting designs that didn't merely copy the video example. All students gained strength points, although points were deducted for not being able to solve the problems themselves without the aid of the help sheets. Courage points were awarded to 57% of the students.

Lesson 2

The next task asked the students to design some coins which could be used to trade with on their journey to rescue the village elder. On the game screen the witch told the students to try and remember how to do the task as they would need to use this quite often when making their castle. To make the coins the video instructed the students to create a series of whole shapes, one of which used the spline tool, thereby introducing the students to more design tools and reinforcing the ones already learned. Once these shapes had been extruded the students had to create a new workplane, and sketch on the surface and add numbers to them. Only around 20% needed help with this task. The main problem the students who needed help had was that their 2D shapes had crossing lines, gaps or small stray lines. Again the students switched places and repeated the task before being awarded strength and courage points. A lower number of 40% received courage points in this exercise.

Lesson 3

Before the students began the third task the witch congratulated the villagers (students) for successfully completing the first level. In conjunction with their strength and courage points this provided positive reinforcement to the students. The intention was to improve their confidence and motivate them to continue with the game and hopefully enjoy using it. This motivation was further reinforced by having completed task 2, which is quite easy, and then attempting task 3, which again is quite easy to complete even though it is part of the next level of the game.

Task 3 asked the students to make a beaker to measure out potions. This required them to draw a 2D shape and extrude, further reinforcing the basic commands previously learned. The students were then instructed by the video clip to select the taper shape by using the taper tool and shell it by selecting a face and using the shell solid tool. Almost no one needed help with this task and 35% were awarded courage points. Most of these points were given because the students had used an alternative simple shape to extrude; however, a few had used the spline tool to create an intricate shape for their beaker.

Lesson 4

The scenario for this task was that the villagers (students) needed to create a box to hide the key in. This task was also reasonably easy and instructed the students via the video clip how to round edges after they had drawn a box shape and extruded it. This again reinforces the basic principles before introducing a new tool.

Before the task started the witch warned the students not to be tricked by Zasnoos' magic and to make sure that they had been shown a preview before selecting 'ok'. Around 30% of students needed help, a vast majority because they had not followed the instruction of checking for a preview and had typed in the same radius that they had been shown on the video clip. Courage points were awarded to 47% of the students for attempting a different design and although many of these were just alternative simple shapes some students had tried more complex shapes such as stars or abstract shapes made using the spline tool. This is an interesting result not only because the students appeared quite confident to try something new, but also because those who had needed help had been reluctant to use any other radius than the one shown on the video clip.

Lesson 5

Task 5 instructed the students to make a bottle to carry potion in. This was completed by using the loft through profile command and introduced the students to creating offset workplanes. An understanding of this concept was important in order for them to navigate around their designs. This was a slightly more complicated task but creates very unique designs as the solid created from the shapes on the workplanes changes significantly with only small variations in the shapes. Not surprisingly around 85% of the students' designs were awarded courage points. When the first student in the pair completed the task, it appeared the students were very unsure as to what they were about to create, despite having a picture in the slide introducing the task. The students were far more enthusiastic when the second student in the pair attempted the task and generally tried to be creative with the design. Only around 20% had needed help and this was often due to two problems. Either the students had failed to create a new workplane and both shapes were on the same workplane causing the model to fail or they had problems selecting the shapes in the correct order when trying to loft.

Lesson 6

This task instructed the students to create a cork for the top of the bottle. Creating the cork was a very simple task and began by using the same method as for creating the beaker. Once this was completed they were asked to assemble the components of the cork and the beaker. This introduced the students to manipulating components and also to the concept of varying scales of the components. Around 40% of students needed help either to select the component, which they found difficult, or to alter the scale of the cork. As neither of these tasks are difficult it may be that the video clip needs to be revised so that it is clearer. Only 20% of students were awarded courage points as most had stuck to a basic circle as the base shape for the cork. Those who gained courage points had mainly used a square or oval shape and only two had created their own shape using the line tool.

Lesson 7

Task 7 asked the students to create a spring using the sweep profile through helix tool. This was quite a difficult task as it involved the students working on two different sketches. The students also needed to ensure that they had a balance between the size of the profile shape and the pitch. It was also difficult for the students to create unique creations as the only variations are the shape of the profile, the amount of pitch and the taper of the helix. For this reason only around 10% were awarded courage points and around 50% needed help.

Lesson 8

In this task the students were asked to create a chalice which they could use to bribe the guards at the castle in order to free the village elder. To do this, they had to create half of a glass shape and revolve it around an axis. Several aspects can cause the model to fail. The half-shape must not have any gaps or crossing lines, the central line must be straight and the axis has to be in the right place so that the shape doesn't try to turn into itself. One further problem the students had was that the video clip didn't show the axis very clearly and this needed clarifying before they began. Those who needed help with this task accounted for 35% of the students. Again only around 10% of students were awarded courage points with most students sticking to the basic glass shape shown in the example.

Lesson 9

The scenario for this task was that the students needed to increase the value of the chalice by adding gems to the stem of the glass. This was completed by creating offset workplanes and sketches around the stem of the glass, which follows on from the lofting task, and drawing gem shapes which they then projected onto the surface of the stem of the chalice. Around 40% of the students needed help with this task as they found the concept of projecting the shape difficult. The main problem included not placing the workplane outside the stem of the glass. Most were able to create an offset workplane but were less able to place it correctly. A further problem was that the students sometimes drew their shapes outside the stem so that they weren't able to be projected onto the surface. Around 35% were awarded courage points for creating more interesting gem shapes.

Lesson 10

In task 10 the students were introduced to rendering by being instructed how to colour their chalice to make it look realistic. This task is quite easy and most students appear to enjoy it. Around 80% of the students were able to be creative in their rendering in that they chose colours and materials that were different to the example. Only 10% of the students needed help and this tended to be because were unable to select specific parts of their models.

Lesson 11

This task instructed the students to repeat the coin task, as the ability to work on a new surface was essential to completing the open task which was to follow. This allowed the students to showcase the skills they had learnt. By repeating the task the basic concepts were fresh in the students' memories.

Lesson 12

In this task the students were asked to rebuild the wizard's castle which in the game scenario had been damaged in the battle to rescue the village elder. The element of choice which the students had requested in the previous study was included, with the students needing to decide whether the wizard was in fact evil or whether he had been under a spell. This was unlikely to change the style of their designs but it did allow them to choose a character to design the castle for. In order to provide a comparison between hand-drawn designs and their computer drawn designs the students were asked to spend this lesson sketching a design for the castle. A castle was chosen for the final task because it allows for a range of different designs and buildings/castles are something that students are familiar with, although often in a 'fairy tale' or 'war'-like scenario. A possible criticism for this task is that castles are often of a similar style with turrets, battlements and drawbridges which, again, might lead to stereotypical designs. At the beginning of the task, students were asked to suggest possible designs and features for their castle and this was written on the board to try and help students think more openly about their designs.

Lessons 13–17

These lessons were spent creating a castle using all the skills they had learnt. During this time the students had access to the video clips so that they didn't have to remember exactly how to complete each command. The students did have to remember what they were able to do in terms of the features available and included these in their designs.

Lesson 18

At the end of this period of study the students completed a questionnaire similar to that which they had completed during the induction day event. Any questions found to be irrelevant to this research in the pilot study were omitted. In all other aspects the questionnaire remained the same in style and wording to maintain consistency. The students also completed an evaluation of their work in the same way as they would have done previously in this programme of study. The intention of the evaluation was to encourage the students to critically consider their own work and the work of others. The evaluation asked the students to write what they liked and didn't like about their own work and then asked others what their opinion of the work was before suggesting ways in which it could be improved. A concern with this process is that students often prefer to use one-word answers or fail to be descriptive in their evaluation and some time needs to be spent by the teacher encouraging the students to fully answer the questions. This evaluation was extremely useful for the purposes of the study as the results could be compared to the answers given in the questionnaire and a deeper understanding of the students' answers could be examined.

6.4 Findings

From the questionnaires 8.5% of students chose number 1 when showing how hard they had found *ProDesktop* to use, indicating that they thought it was easy to learn. Number 2 was chosen by13%, 53.5% chose number 3, 18% chose number 4 and 6% chose number 5, indicating that they had found it hard to use. When compared to the answers the students gave in the first questionnaire in Study 1, 30% of students found *ProDesktop* easier to use than they had expected, 34% found it as difficult to use and 36% of students found *ProDesktop* harder to use than they expected (see Table 6.2).

Some 53% of students chose number 1 for enjoyment, indicating that they had enjoyed using the program (this is an increase of 19% from the previous study), 27% chose number 2 (an increase of 4% from the previous study), 14% chose number 3 (a decrease of 5%), 3.5% chose number 4 (a decrease of 13.5%) and 2.5% chose number 5 (a decrease of 4.5%). When compared to the answers given by the students in the first questionnaire in Study 1, 25% of students found *ProDesktop* more enjoyable to use than they had expected. 39.5% found it as enjoyable and 35.5% found it less enjoyable than they had expected. Although the amount of students whose enjoyment had increased or decreased between the first and second questionnaire were similar to that of the previous study, the amount of students who had expected to enjoy using the program and then had actually enjoyed using the program were far higher in this study than the previous study (see Table 6.3).

Table 6.2 Level of difficulty experienced when using* ProDesktop *and a comparison with the pre intervention questionnaire

	Study 3
Level1 – easy to use	8.5%
Level 2	13%
Level 3	53.5%
Level 4	18%
Level – difficult to use	6%

	Comparison with pre-intervention questionnaire
Easier to use	30%
As easy to use	34%
Harder to use	36%

Table 6.3 Level of enjoyment experienced when using* ProDesktop *and a comparison with the pre-intervention questionnaire

	Study 3	Comparison with Study 2
Level 1 – enjoyed	53%	Increase of 19%
Level 2	27%	Increase of 4%
Level 3	14%	Decrease of 5%
Level 4	3.5%	Decrease of 13.5%
Level 5 – did not enjoy	2.5%	Decrease of 4.5%

	Comparison with pre-intervention questionnaire
Enjoyed more	30%
Enjoyed as much	34%
Enjoyed less	36%

When comparing results regarding student attitude to how difficult they found 3D SMCAD to learn, 23% of students indicated they had found it harder to learn. Interestingly, although a larger number of students had found the program harder to use than they had expected, they had not found it any less enjoyable.

From comparing the results of the two questionnaires five groups of students were selected to be interviewed regarding their opinions and why they believed they felt the way that they did when using *ProDesktop*. The groups were chosen because their views had changed significantly from expected enjoyment to actual enjoyment either positively or negatively. The difference in these groups' chosen levels between expected enjoyment and actual enjoyment were at least three levels apart. The students were interviewed in groups according to their normal class sets; therefore their experiences would be the same and they would be more familiar with each other. A further group of Year 8 students were also interviewed. As this was a much smaller sample this included all of the more extreme responses and took more of the form of a case study approach.

Group 1 – enjoyed using *ProDesktop* more than they thought they would

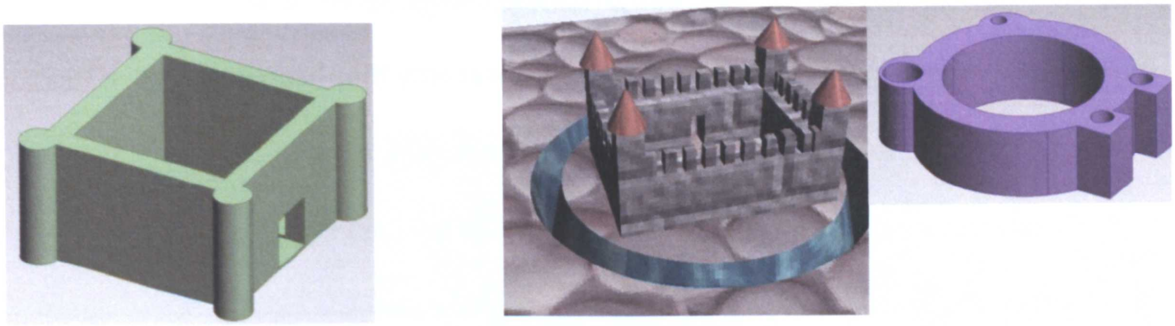
6 participants: AK, LA, JM,SW,EG and DM

This group had chosen level 4 or 5 for expected enjoyment before using the program, but then had chosen only level 1 or 2 for actual enjoyment once they had experienced using it.

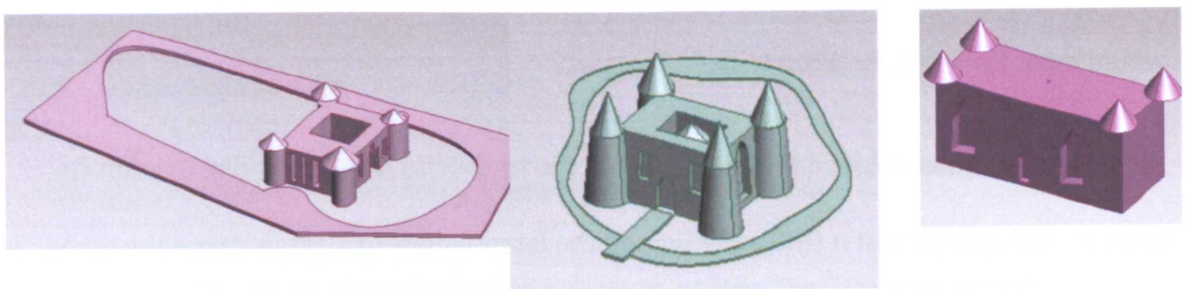
The interview began with a reminder of the project. AK immediately said 'Oh yeah! I made my castle look like a gladiator ring.' When asked what the others enjoyed about using *ProDesktop*, SW said that he had enjoyed being able to make all sorts of stuff, especially as he couldn't draw very well. EG agreed and said that it was much better than drawing as it looked better in the end. LA added that he really liked that you could make things 3D as this would be really hard to do if you were drawing. JM said that he liked the challenge, it was difficult but it was really good to be able to do it.

When asked what they thought about the game and video clips, AK said that he thought there should be more detail in the game as it was a bit basic adding that he had found that the video clips had skipped in places and he had missed bits, which was frustrating. EG was positive about the game and said that she liked that you could work at your own pace and that made her more confident to try using it. She also liked that the clips showed you what the controls looked like and where to find them. DM agreed and added that she liked the story line as it made it more fun than just making stuff.

AK believed he had been creative as his castle didn't look like anyone else's, but added that he would have liked more time to complete his castle as he had restarted once to make his better and it had taken longer than he had expected. JM said that when they had looked around everyones' idea was different. DM agreed and said it was fun to see how others had done theirs (castles). The others were unsure if they had been creative or not. AK liked working in pairs adding that you can work through any problems you have with them. LA liked that if you couldn't do something then your partner usually knew how to do it or if you were confused they could help work it out with you. SW said that he liked that you could work on two computers in pairs so you didn't have to keep switching between screens. DM and EG agreed that they liked working in pairs but didn't offer any further comment. JM said that he didn't like working in pairs because it made it more difficult if you wanted to try something different and your partner didn't want to. He added that by having a partner he didn't get to work on *ProDesktop* as much as he would have liked, because he had to do the video clips half of the time (see Figure 6.1).



LA SW AK



JM EB DM failed to save

Figure 6.1 Group 1 students' work following intervention trial

Group 2 – didn't enjoy using *ProDesktop* as much as they thought they would

5 participants: HH, DK, HR, ET and KW

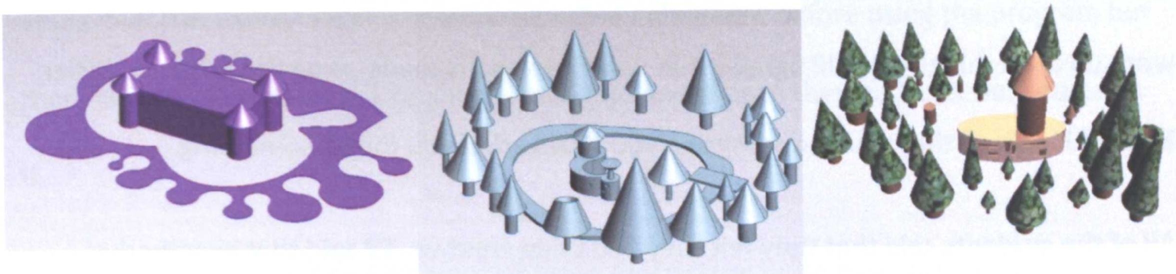
This group had chosen level 1 or 2 for expected enjoyment before using the program but then had chosen level 4 or 5 for actual enjoyment once they had experienced using it.

As part of the introduction the students were told that they had been selected to take part in the interview, as they had indicated on their questionnaires that they hadn't enjoyed using *ProDesktop* as much as they thought they would. HH immediately said 'Nooo!' in an exaggerated way and was asked to expand on his response. He said that the program had been far too complicated and that he didn't think that it was something that they should be learning until at least Year 9. ET, KW and DK agreed and said they had found *ProDesktop* far too hard to use and said this was why they hadn't enjoyed using it. ET and KW had also worked as a pair throughout the project. HR said that she found she had missed steps on the video clips and that had made her confused. HH said that he would prefer the instructions in written form and that he was 'too stupid' for the video clips, possibly indicating low self-esteem. HH was asked if he thought he would read the instructions or just ask for help, and he initially said he would read them but agreed he would most likely ask for extra help.

HH said that he had enjoyed the game part of the lessons as he liked having a target to work to. KW agreed that it (the game) made the lesson more fun. HR said that the game made the program easier to understand as you knew why you were making things rather than just creating random objects for no reason. HH said that the game would be even better if you could choose the scenario, so you could, for example, choose between the castle scenario or a spy scenario. KR agreed and said that she would also like to have a choice in the things they make, for example they could choose between making a magnifying glass or a pair of binoculars in the spy scenario.

HH said that he didn't feel the castle he had made at the end of the project had been creative but he had in fact made a chicken-shaped castle initially (not shown as the student had deleted it) which had been considered quite creative. HR said that her's had looked like a banana but that she hadn't intended it to look that way. KW said that she had wanted to try to be creative when making her castle but that she hadn't been able to use *ProDesktop* well enough so it hadn't turned out the right way.

All had enjoyed working in pairs for similar reasons as Group 1. They all stated that if they got stuck they could work through it together, which made it easier to do.



HH HR ET

DK and KW failed to save

Figure 6.2 Group 2 students' work following intervention trial

Group 3 – didn't enjoy using *ProDesktop* as much as they thought they would

5 participants: JP, HM, EP, AP and HR

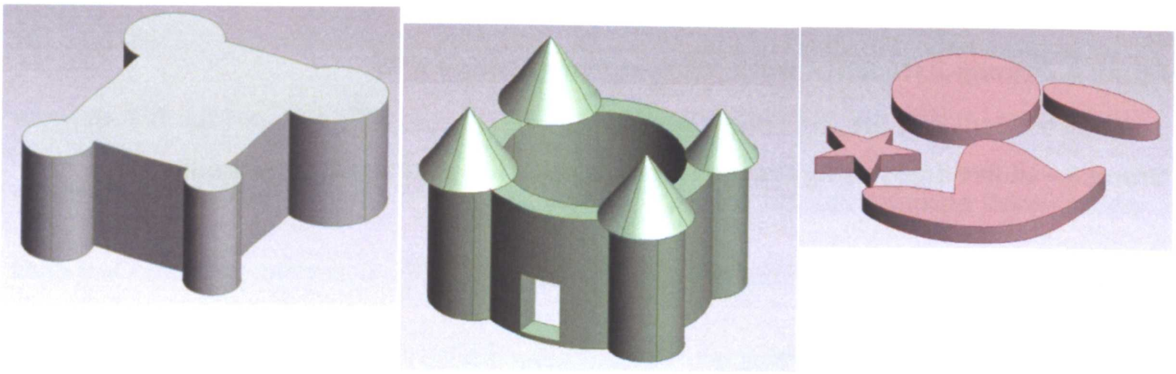
This group had chosen level 1 or 2 for expected enjoyment before using the program but then had chosen level 4 or 5 for actual enjoyment once they had experienced using the program.

When asked what the students liked or disliked about using *ProDesktop*, AP said that she had found using the program boring. EP said it had been too complicated to use and the others agreed. HR said she had found it difficult to know what to click on but added that it was good to make things once you had got the hang of it. All of the students said that they had enjoyed making the castle.

AP said that she had found the videos confusing as they weren't very clear. HM said that it would be better if they had sound and JP said that he would like a better explanation of why you were doing what you were doing. HM found the game, especially the skill and courage marks, a bit pointless and said it hadn't motivated her at all.

All of the students preferred working in pairs. HM said that it helped to have someone to work through things with. JP agreed that working in pairs made using the program easier. HR said it helped that you had someone you could ask if you forgot something.

All of the students said that they felt they had been creative. EP said that everybodys' looked different and HM agreed that the castles were individual and that when you looked at other peoples no one had had that idea (see Figure 6.3).



AP JP HM

EP and HR failed to save

Figure 6.3 Group 3 students' work following intervention trial

Group 4 –enjoyed using *ProDesktop* more than they thought they would

6 participants: FF, MD, CH, CB, JC and AH

This group had chosen level 4 or 5 for expected enjoyment before using the program but then had chosen only level 1 or 2 for actual enjoyment once they had experienced using it.

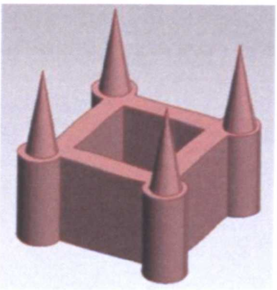
FF began by saying that he had enjoyed using *ProDesktop* as he had liked being able to make something that he wouldn't have normally been able to make. MD added that he had especially liked being able to make his ideas 3D. FF also liked that you started with the simple things but moved on to the harder things quite easily. CH said that he had found using the program hard but it was one of those things that you just had to learn.

FF, MD and AH all said that the video clips had helped. AH liked that it showed you an example of what the item you were making should look like, which you could then change. MD said that it would be better if it was slower, though. This seemed an unusual comment as the student had control of the video clip and could play it at a pace to suit the group.

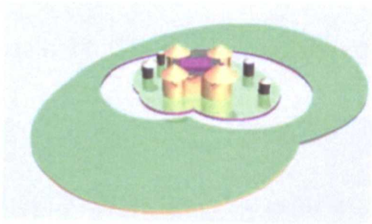
AH had found the game idea a bit silly at first but said that you get used to it and then it makes a lot of sense. CH said it was a good idea but hadn't realised it was a game. FF had found the game aspect encouraging and it had made him try harder. AH said that she thought that the boys especially would want to win and would therefore try harder.

Again this group had enjoyed working in pairs. MD said he had liked that there was someone to compare ideas with and that you could try to make it better. CH said it was good that you had someone to talk through problems with and it helped to explain what you were doing. AH agreed and said she liked that if you didn't understand then they often would.

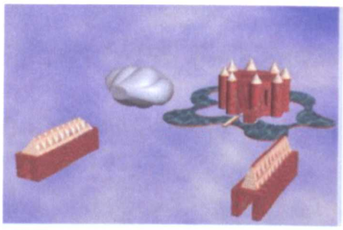
When asked if the students thought their ideas were creative, they all said yes. MD said he had liked that his castle had a jacuzzi and battlements at the top. CH said he liked that his castle had been his own choice and he had been able to do what he wanted with it. Both AH and FF said that they thought they had been creative when adding colour to their designs (see Figure 6.4).



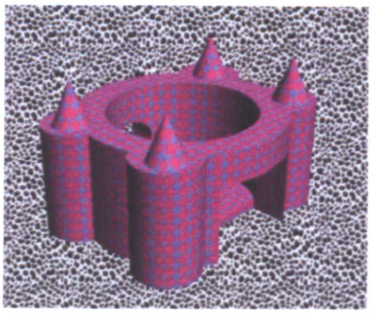
FF



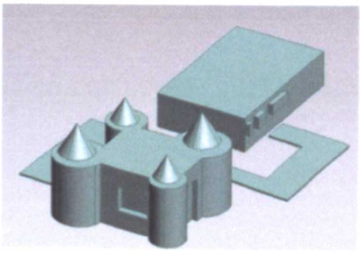
CB



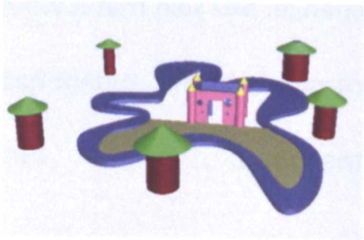
JC



AH



MD



CH

Figure 6.4 Group 4 students' work following intervention trial

Group 5 –enjoyed using *ProDesktop* more than they thought they would

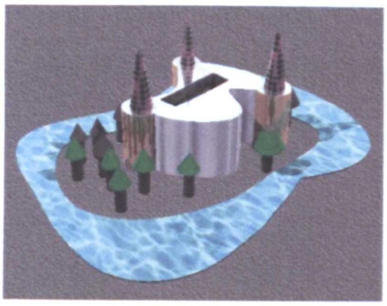
8 participants: KL, AM, LP, MH, DJ, JR, JS and JT

This group had chosen level 4 or 5 for expected enjoyment before using the program but then had chosen level 1 or 2 for actual enjoyment once they had experienced using it.

JR started the discussion by saying that he had found the work to be a hard challenge but had enjoyed using *ProDesktop* because it was something that you wouldn't normally do. JS said that he had found using the program easier than he had expected, which was why he had liked using it. KL and LP said that they had found using the program hard but that it had been a lot easier with partners. JR agreed and stated that working in pairs was good because often they remembered stuff that you didn't. JT said that he liked that you had a video that told you what to do as this had made it easier for him. JR agreed and said that it had made it a whole lot easier. KL also agreed and said that she had liked being able to work on two computers at the same time, as you didn't need to keep switching screens. MH said that he had found the work fun and easy and added that he would have found it a lot harder if he had been working on his own.

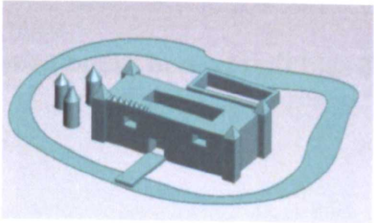
KL hadn't enjoyed the game aspect; she said it took too long and that they had had trouble getting it to run properly. JR had enjoyed the game as he liked the competition and it had made him want to do well and learn the program. JS said the game had motivated him to do better.

All said that they had found creating the castle hard. JR said that he hadn't been able to finish his in the time given and would have liked more time to finish it better. KL said that she had not been able to make the castle to start with and that by the time she had worked out how to do it it had been the end of the course. LP had lost her work and had to start again, which she hadn't liked, but thought her castle was creative because of the way she had put pyramids on it, whereas others had put battlements. She had also liked it because they got praise from other classmates and she found it motivating when someone said they liked what she was doing. KL liked that it didn't matter if it went wrong because it took the pressure off and you could always put it right or start again and it got easier as you went along (see Figure 6.5).

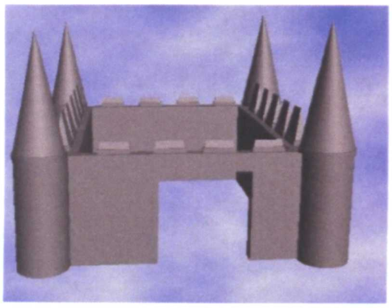


KL

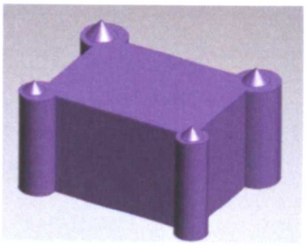
AM



LP



DJ



MH

JR

Figure 6.5 Group 5 students' work following intervention trial

Group 6 – Year 8 students

5 participants: 3 males and 3 females – JC, MR, RG, SB, AK

This group was chosen through observations made by the interviewer rather than questionnaire response. Each student was chosen either because of a marked change in attitude or because of their different roles in the paired learning element of the activity. A brief summary of the students involved and the reasons they were chosen follows before the findings from the interview.

JC was very enthusiastic about using *ProDesktop* throughout this study. In the previous study he had indicated on his questionnaire that he had expected not to enjoy using *ProDesktop* but had actually enjoyed using it a lot. Through each task JC was extremely keen to gain courage points by making his products different from the example. By the end of the project he had gained the highest amount of courage and skill points in the year group. To achieve this he had combined different shapes and skills regardless of whether of whether or not the students were expected to use them in the task. For this project JC had worked in a pair with RG. RG had indicated a middle response in the first questionnaire and had kept this response in the second questionnaire. In this study RG seemed reluctant to get involved with using the program and appeared to prefer controlling the instructions. These two were chosen for interview because working as a pair appeared not to be successful in this instance, that is, JC was so enthusiastic and had a high level of skills and RG was reluctant to use *ProDesktop*. At the end of the study JC again indicated on the questionnaire high level responses and RG maintained a middle level 3 response to both questions (see Figure 6.6).

Figure 6.6 JC and RG's work following intervention trial

MR was also interviewed in the previous study as he had indicated in the first questionnaire that he did not expect to enjoy using *ProDesktop* but in the second questionnaire selected that he did actually enjoy using it a lot. In this study, although indicating a high response in the questionnaire, MR seemed less interested in using *ProDesktop* than he had been in the previous study and was easily distracted by his friends. MR was included in this study to ascertain a reason for this change in focus.

SB had indicated a decrease in enjoyment in the first study and had stated that the reason for this was because she had found the program very difficult to use. In this study SB seemed very enthusiastic and appeared very keen to take her turn using *ProDesktop*. The student completed all the tasks well, gaining strength points and had made attempts to produce creative results. In the final task the student produced several designs in which she had obviously tried to be creative, gaining courage points. These outcomes were less successful in terms of skills and therefore strength points (see Figure 6.7).

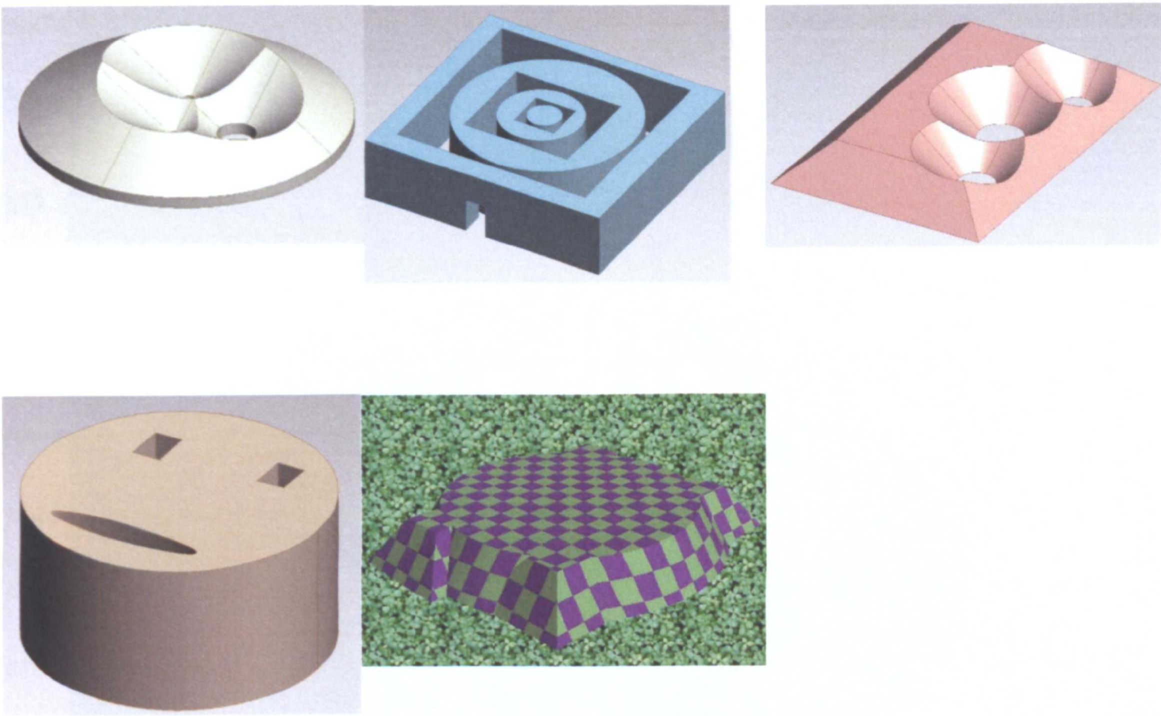


Figure 6.7 SB's attempts at the final task

AK has a very low attendance rate as she does not enjoy school and has a high number of 'unauthorised absences'. In the previous study she failed to complete the first questionnaire and indicated a middle level3 response for both enjoyment and difficulty when using *ProDesktop* in the second questionnaire. AK was included in this study because she appeared to enjoy using the program this time. This was identified when she chose to work alone and spent a considerable amount of time on the final task. She appeared to have a clear idea of the design she wanted to produce and was keen to develop the skills necessary to achieve this. This even included (with help) the addition of a bird in the sky of the design, which was difficult to complete. AK was very proud of the end result, taking a copy of the design for her head of house and her parents to see. AK indicated at the end of this study that she had enjoyed using the program but had found it difficult to use (see Figure 6.8).

Figure 6.8 AK's work following intervention trial

During the interview, JC said that he had enjoyed the element of competition in the game and was very keen to get as many points as possible. He stated that as RG wasn't interested in using the program and he (JC) thought he was better at it they could gain more points if he did the *ProDesktop* work. When asked how he felt about this, RG said he didn't mind, he 'wasn't that bothered about being on *ProDesktop*'. RG expanded on this by stating that it was because it wasn't the sort of job he would do when he left school. He said he was keen to do well but quite happy to take a back seat and watch JC do the *ProDesktop* work. He said he believed he had had an input as he had made suggestions throughout all of the tasks which had often been implemented by JC. When asked how they thought this had affected their learning neither student seemed to think it was a problem and thought it had worked well. JC also liked the idea of the video clips as he could work at his own pace, which he thought was better as he had felt he had been held back in the last study and had got bored at times.

MR was then asked his opinion of the project. He said that he thought he had done okay and had enjoyed the study, especially as it had been his idea in the last interview to use a wizard scenario and he was pleased it had been used. When the interviewer stated that he seemed less focused this time MR was animated in his response, saying that he had enjoyed it just as much but that he had been distracted by friends in other groups. He didn't feel this was particular to this subject but thought he was probably the same in other lessons. MR stated that he wasn't that bothered by the element of competition but had enjoyed the interaction with the video clips and his partner. He agreed that he could have gained better marks if he had remained on task.

Both SB and AK gave similar responses when asked why they seemed to enjoy using the program more. Both said that they 'get it now' and this had given them the confidence to try different things. AK added that she had enjoyed it because she could make designs that she wouldn't have been able to draw as well and also had been more able this time to make the design look how she had wanted it to on the computer. SB said she liked the element of competition and that this had made her try harder. Although her final designs hadn't worked out as well as she had hoped, she said she was still pleased with them and thought she had used more skills. AK was more focused on the video clips and said she liked that she could look back over things so she didn't have to keep asking for help.

Only the creative outcome of the Year 7 students' designs was considered because other factors such as experience may have affected the result of the Year 8 work. When considering creative outcome, 38% achieved a level 1 by showing high levels of creativity (an increase from the previous study of 28%), 38% achieved a level 2 by showing some creativity in their designs (an increase of 13% from the previous study) and 24% gained a level 3 by showing little or no creative outcome in their designs (a decrease of 41% from the previous study). This result indicates that the students had been considerably more creative in their designs when using this method of teaching.

6.5 Reflection on Study 3

A far higher number of students expected to enjoy learning *ProDesktop* and then actually enjoyed using it following a programme of study using this alternative method of teaching. This further validates the conclusion made in the previous chapter which suggests that if the students expect to enjoy using the program then they will actually enjoy it. Perception of difficulty appears to make little impact either on how much the students will enjoy using the program or on the final outcome. Attitude to the perceived difficulty does seem to make a difference, however. Those who expected to find the program difficult to learn and who also enjoyed using it either enjoyed the challenge or saw the difficulty of the task as something they just had to get on with. Those who expected to find the program difficult to learn but had actually found the program hard to learn had also not enjoyed using the program and usually saw the difficulty as a barrier and thought it was just too hard.

Most students, even those who had indicated that they hadn't enjoyed learning *ProDesktop*, said they had enjoyed the game aspect of the learning and saw the task as more fun to do. Some said that it made them feel more confident to try things. Others said that the competition element made them try harder. One student said that they liked that you got rewarded even if your design didn't work, as it took the pressure off and allowed them to try new things. A small number of students found the game scenario a bit silly and suggested that there should be other scenarios that they could choose from. This appears to support the idea that students enjoy the elements of challenge, reward, idea support, play and risk-taking, all aspects that are recommended for providing an environment suitable for fostering creative behaviour.

Almost all of the students regardless of how much or little they enjoyed using *ProDesktop* liked working in pairs. Only one student said that by working in pairs he had not spent as much time as he would have liked using the program. Others found being able to work through problems and being able to discuss ideas with someone beneficial. Although not expressed verbally the tone of the discussion during interviews suggested that the students felt more confident by having someone to talk to if they didn't understand something. One concern was a pair of Year 8 students who had appeared not to work well as a team, because the same person used *ProDesktop* all of the time. Both students seemed happy with the situation and did not believe they had missed out, as the student in control of the instructions had had an input into the designs and had seen the features being used. It is possible that although, on the face of it, the pair did not appear to work together, it had been successful. More research would be necessary to establish whether this is the case.

By using video clips that the students had control over to show them how to achieve each task, they could work at their own pace. This appealed to the students, as those who grasped the basic concepts easily didn't get bored and were continually challenged and the students who needed to spend longer weren't rushed and could take the appropriate amount of time on the aspects that they needed to. This method appealed to both the visual and the kinaesthetic learners. Sound had not been added to the video clips as this may have prevented the students from discussing their ideas with each other – because to avoid disturbing other students this would need to be delivered through headphones. One student, however, said he would prefer to have sound with the videos. This would appeal to the auditory learners and could be added to the videos easily. It is possible that they could use sound and interact with each other; however, careful monitoring would be necessary to establish whether it was beneficial. One student also asked for written instruction, claiming he 'was too stupid for the videos'. Written instruction was provided to help the students to problem-solve; however, providing written instruction for all of the tasks may be more appropriate for some students. Providing a range of resources to suit a range of learning styles and preferences may help the students to feel more confident in their learning and would allow differentiation for weaker students without making the student feel less able.

Undoubtedly the castles in general displayed a greater level of skills and creativity and more students managed to complete and save their work than in the previous study. The castle designs mainly consisted of extruding either simple or more complex shapes and then adding turrets, trees and moats using the extrude and taper feature, although the way in which the students used those basic tools were quite diverse. A few more confident students used the more complex loft or revolve feature. When asked whether students thought their work was creative, discussion included features in the castle and the way in which they had used the tools, unlike in the previous study where discussion had mainly involved colour and pattern.

6.6 Conclusion

This programme of study was more successful in producing creative outcomes from the students than the traditional method of teaching 3D SMCAD in schools to Key Stage 3 students. This appeared to be for several reasons, although different students cited different reasons for successful outcomes or enjoyment when using the program. Almost all of the students liked working in pairs and this appeared to give them confidence to work through problems and try different ideas. Some liked the element of competition and this helped to make them try harder. Those who hadn't been encouraged by the competition did not appear to have been discouraged either but had simply ignored this part. Choice and diversity in the resources seemed to appeal to many students as they had different learning preferences and this could be extended further by introducing sound to the video clips and more written instruction.

By including many elements it seems that students will use what they want to and disregard the others to suit their own learning needs. While this has been successful in one school with a teacher who is experienced in teaching CAD delivering the lessons, further research is needed to establish whether it would also be successful with a less experienced teacher or in other schools where attitudes and experiences may be different.

Chapter 7 Results of Studies 4A and 4B

Study 4A – Examining student and teacher attitude and outcome when intervention is delivered by an alternative teacher

Study 4B – Examining student and teacher attitude and outcome when intervention is delivered in an alternative school

7.1 Introduction

Chapter 6 reported on student attitudes and the outcome of their work following a programme of study using an alternative method to learn 3D SMCAD.

This chapter reports on the implementation and effects of an alternative method of teaching 3D SMCAD both in the same school with a teacher who is less experienced in teaching CAD and in another school with a different teacher. The teacher from the alternative school has expressed an intense dislike of the *ProDesktop* program and therefore an alternative perspective on the teaching method is offered.

7.2 Methods

Table 7.1 Summary of research methods used in Study 4a and 4b

	Study 4A	Study 4B
Pre-task questionnaire	/	/
Post-task questionnaire	/	/
Spatial awareness test		
Creativity assessment	/	/
Semi-structured interviews		
Teacher diaries	/	/

To test the reliability of the data gathered the alternative method of teaching CAD was tested both in the same school as in the previous studies with a different teacher and in another school with a different teacher. In order to maintain as much consistency as possible resources and research methods were identical to those used before. One difference to the previous studies was that in order to reduce the pressure on the teachers participating in the study the alternative method was only delivered to one class of up to 26 students in each school rather than to the considerably larger sample size used before. In total the sample still included up to 52 students in order to provide a range of experiences and opinions.

As in previous studies, students in the alternative placements were shown an example of 3D SMCAD before completing the same questionnaire used at the start of Studies 2 and 3, which related to how much the students had expected to enjoy using *ProDesktop* and how hard they had expected to find using it. Following the completion of the programme of study, students completed the second questionnaire relating to how hard the students had actually found the program to use and how much they had actually enjoyed using it. The results of this were then compared to the previous questionnaire in order to assess whether the students attitudes had changed. Most importantly in this study the attitudes of the students were compared to those who had participated in previous studies to gain a deeper understanding of the effects of instructor attitude on the students. Again, as with previous studies, the students work was graded according to creative outcome by the same set of teachers who had judged the work before.

An addition to the research findings is that of teacher opinion, which had not been considered previously as the teacher in the previous studies was experienced in using and teaching CAD software. In this study the instructor was asked to keep a short diary or blog of their experiences during the lessons in order to further assess the effects of instructor attitude on the students' progress and work. Finally an interview was conducted to clarify any issues and to gain a deeper understanding of the teachers' experiences.

7.3 Study 4A – Testing the alternative method of teaching CAD in the same school with a different teacher

Due to curriculum issues within the school the group that the teacher was to deliver the programme of study to was only allocated 8 lessons instead of the intended 18. This was an exceptionally tight timescale. Therefore the teacher who had delivered the programme of study in the previous study introduced the topic to the class to speed up the students' completion of the questionnaire and understanding of what was expected of them. During this lesson the students were shown an example of CAD and asked to fill in the first questionnaire and the scenario at the start of the game was read to them. The teacher who was to deliver the rest of the programme of study took control of the group from this point. The students were asked to select their own partner to work with and started the game by completing the key task. The teacher was experienced in classroom management and was able to use the *ProDesktop* software but was less confident when using or teaching it than the teacher who participated in the previous studies and often struggled to rectify issues that cause the 3D model to fail when they occur. The class consisted of 19 students of mixed ability; 7 had a recognised special educational need but did not have a statement within the group. These students did not receive teaching assistant support but may have required additional resources or help to aid them in a lesson. The mix of gender within the group was almost equal, as ten of the students were male and nine were female.

In addition to the time constraints a further concern was that of the *ProDesktop* program itself. The computers in the room did not have sufficient graphics capability and therefore it was necessary to complete a short command sequence to disable some of the graphics elements of the program. If students failed to do this before starting the program the computer mouse appeared to freeze and objects did not appear 3D on the screen even if subsequent command sequences had been completed correctly. This was not documented in the previous studies as the teacher was more experienced and had instructed the students to complete the command sequence as a matter of course, and it hadn't caused any problems in the lessons.

7.4 Findings from Study 4A

7.4.1 Teacher diary

The following provides a summary of the findings from the diary kept by the teacher involved in this study. The full diary can be found in Appendix 12.

The teacher was generally positive about the intervention and in commenting on the work that the students had completed in the final task stated that it was 'very rewarding to see such a high level of outcome'. Students were able to complete most of the tasks and some of them were able to be creative with the designs. She noted that the students seemed to enjoy some of the difficult tasks, such as the helix, and were able to complete these easily. This was different from her previous experiences in teaching using the program. The teacher noted for a few lessons that the students 'are not showing any signs of being phased by the tasks and are keen to move on'. This perhaps demonstrates that students are more motivated by this method of teaching. One of the tasks the students found difficult involved revolving a shape to form a chalice. The teacher believed that the difficulties with this was because the video clip jumped a little and students weren't able to see the revolve line that was necessary to make the task work. An aspect the teacher found particularly useful was the help sheet known as 'Zelda's magic book' as she could use this to help the students when she wasn't sure what to look for when the student was stuck. Most of the negative points made in the diary kept by this teacher involved issues with the computers and the student pairings, which she felt worked against the benefits of the intervention as the two excerpts from the teacher diary below demonstrate. The first reports on problems encountered with the computers:

> A few students had not done the sequence of tools, options, performance as requested and therefore their computers were not responding properly. I had mixed feelings at the end of this session as the students who had opened the programs quickly were quite obviously the ones that then went on to read the game instructions and complete the task. The other students struggled throughout and two failed to get both programs open and ready to go.

The second reports on issues caused as a result of some of the pairings:

> The main problem today seemed to be that some of the pairings were showing signs of cracking. This problem was mainly confined to the male pairings with accusations about 'not reading instructions out properly' or 'not listening to what I'm saying' ...The girls on the other hand excelled particularly in this session completing three tasks, the box, the bottle and the cork, in one go.

Another complication she noted centred on students not reading the instructions either because they had low literacy skills or because they were 'too lazy'. Although the video clips include the option of listening to commentary, using this is not encouraged as it could prevent students working effectively in pairs because of reduced communication between them. However, for some students who struggle with written instruction this may be a useful alternative. The teacher's final criticism involved some students not knowing what a 'workplane' is or does, which had prevented some of them moving on successfully in one of the tasks. Although an explanation of this appears in the help sheet, it is possible some more instruction before starting the task might be useful.

7.4.2 Teacher interview

As with the students' interviews a semi-structured format was adopted to ascertain the instructor's opinion of the teaching method.

The teacher was first asked her opinion of the teaching method. She replied that in principal the method was good. In comparison with the previous groups she had taught *ProDesktop* to using the traditional teaching method, and who had approximately 18 lessons instead of the 8 this group had, this group had achieved far greater results. She felt that the students were much better at following the on-screen instructions and did not hesitate to try even if mistakes were made. As they moved through tasks more quickly than previous groups they did not get the chance to become bogged down with the same drawing and each lesson brought at least one if not two fresh challenges to be solved. Often students were confident enough with the program that they offered to help those who were still struggling slightly. One of the teacher's main concerns was that of paired learning (CSCL); the group had not taken well to working in pairs even though they were able to choose their own partner. She continued that for every two pairs that worked through problems together there was one pair that argued and didn't think their partner was reading out the instructions properly or that they weren't helping enough. She also believed that the students who were reading the instructions didn't enjoy doing that and they always wanted to be the one on *ProDesktop*. She said that she would have preferred it if this group had been allowed to work on its own; however, this would have required dual screens which most schools did not have. A further concern was the quality of the computers she was using as she had had to spend quite a bit of time at the beginning of the lesson dealing with computer-related issues rather than teaching ones. When asked her opinion of the breadth of content covered in the scheme of work she stated that although more time could have been spent on each task if they had been allotted the 18 lessons instead of 8, she liked the pace and believed it was an excellent introduction to the program as the students could see what it was capable of. She continued that a later scheme of work could focus on each feature in more depth. This exercise had given the students the confidence to try the program and not get over fazed by it. It should be noted that due to the time constraints the students had not spent much time on the castle task and had concentrated on the more basic features at this time. It is often during this task that students feel that they are unable to do the work and need extra guidance, support or encouragement. When asked whether she believed the students had been creative she said she was amazed by the variety of designs they had managed to achieve and this certainly wouldn't have been possible in eight lessons when teaching using the more traditional method. Finally the teacher was asked whether she would use this method of teaching again. She replied that she would use a combination of both methods because although she liked the freedom the video clips gave her she didn't like the arguments and believed this was detrimental to the outcome. She would perhaps allow certain students to work in pairs and follow the game but with other students she would provide them with more of the follow-my-leader-style teaching method.

7.4.3 Student opinion and work outcome

In the initial questionnaire, 53% of students chose number 1 or 2, indicating that they expected to find the program easy to use and a high percentage of 70% chose 1 or 2 for enjoyment level, indicating that they expected to enjoy using the program. Once the students had completed had completed the programme of study, 35% said they had found the program easy to use and 48% indicated that they had actually enjoyed using the program. This is a lower number than in previous studies; however, more had expected to find *ProDesktop* easy and enjoyable to use before using the program than in the previous studies.

Again, regardless of student opinion and considering the students only had half of the time the students had in the previous studies the final work displayed a greater level of ability and creativity than had been achieved through the traditional method of teaching CAD. Some 50% of students achieved a level 1 for creativity, 30% achieved a level 2 and only 20% achieved a level 3. The results compare well to Study 3 with a 12% rise in those students achieving a level 1; however, there is a decrease of 8% at level 2. This is a significant result as the students not only had half the amount of time than the students in Study 3 but also had a less experienced teacher and a relatively high number of students with learning difficulties. Although many of the variations in their designs centre around creating different shapes to extrude, working on new surfaces and using the taper tool, almost all of the students attempted to create designs that differ from the example given and from each other (see Figure 7.1). Given more time the students may have achieved even greater results.

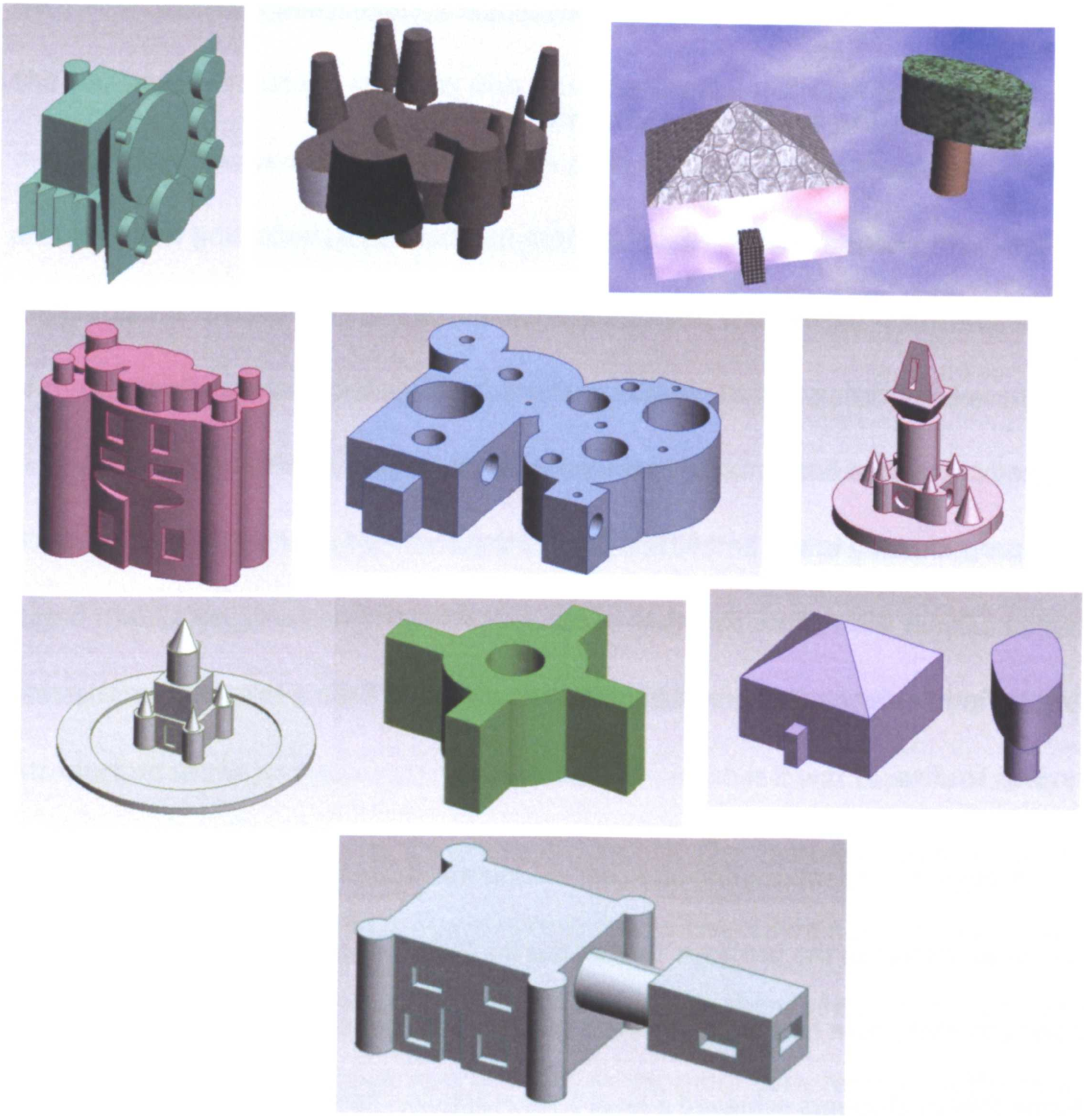


Figure 7.1 Study 4A students' work following intervention trial by a different teacher

7.5 Study 4B – Testing the alternative method of teaching CAD in an alternative school

The alternative school that the teaching resources were tested in was a large school in Huntingdonshire with 1850 students of mixed sex and ability on roll. The technology faculty was also relatively large, employing ten members of staff who taught various components of Design and Technology. At that time the department had an emphasis on teaching more traditional techniques in Design and Technology lessons; however, the staff and head of faculty were keen to introduce more up-to-date facilities and programmes of study, although computer facilities and CAD/CAM equipment were limited. The department had one room of 24 computers in reasonable condition and specification and no overhead projector for the teacher to demonstrate on.

The teaching of CAD programs in the school had been always been through a variety of relatively easy to learn programs such as *Google Sketchup* and *Techsoft* 2D design delivered in short focused periods of study. At the time the study took place the teacher intending to implement the new program of study was fearful of using 3D SMCAD programs and had expressed an intense dislike of *ProDesktop*. To ensure a consistent approach to the lessons in this and the previous school the researcher visited the teacher at the school to discuss how the resources should be used. The intended teacher experienced some difficulties with the PowerPoint presentation and the video clips during this session but felt confident enough to try the method with a class within a week of the visit. The resources were used with one class of 22 students of mixed sex and ability in pairs that the teacher felt was appropriate over a period of eight 50-minute lessons. This was consistent with the length of time the previous school had allocated to Study 4A, although again significantly lower than in Studies 2 and 3. One concern the researcher had was that a two-week holiday would split the program of study and as a result an extra lesson in which to recap previously learned skills may have been required.

7.6 Findings from Study 4B

7.6.1 Teacher diary

The following provides a summary of the findings from the diary kept by the teacher involved in this study. The full diary can be found in Appendix 12.

The tone of this diary was much more conversational than the one the previous teacher had kept in Study 4A, and fully demonstrated the fear and difficulties that teachers can experience when teaching CAD to a class. The diary began with a frank description of his feelings at having to teach *ProDesktop*. As stated earlier, teaching CAD is an important part of the curriculum and if it continues to be taught an alternative method of teaching is essential in helping teachers with similar views to this.

> The fact that I'm writing this means that today, the day I have been dreading has arrived. It seems silly that the thought of 50 minutes of teaching can put such fear into a mans' heart. ... it's the thought of working with *ProDesktop* again.

He continues,

> They spent hours trying to teach it to me at Homerton [Homerton College, Cambridge]. Since then, Homerton teacher training students have tried to teach it to me on their placements here.

Department staff have been away on courses on how to teach it and yet still none of us can. Or at least we can until something goes wrong and we can't trouble shoot the problems for the students and neither can they for themselves. The software has no credibility with us at all so why should it change now? It's like going into a lesson knowing you are going to teach the student from hell.

Once the lesson had begun with the teacher using the intervention, the tone of the diary becomes more positive and ends that day's lesson with the note: 'how did it go? Well to be honest, not too bad'. Compared to the opening statement this is very pleasing from the teacher's point of view.

This teacher quite often reverted to other methods of teaching in conjunction with the intended student-pair-based method of teaching. Sometimes this involved sketching, using an overhead projector or asking the class to give a step-by-step account of what they had done. This was to reinforce the knowledge embedded in the video clips and game. While this was not expected in the intended teaching method, it did not harm the outcome, although perhaps greater emphasis was placed on remembering sequences than necessary. A further difference in the teaching method was that the teacher appeared to prefer the students to all work at a similar pace so that he could stop them and go through any problems or through the underlying knowledge together, instead of allowing them to work at their own pace. This may have been due to the teacher's lack of confidence.

Initial problems reported by the teacher involved general problems with the computers, largely that the students struggled to access the video clips with their given computer permissions; however, unlike Study 3 no problems with the student–student pairings were reported.

Problems involving the intervention occurred when the teacher struggled to identify crossing lines and gaps in the students' work because he had forgotten to use the help sheet or 'Zelda's book of spells' Once he had remembered, many of the minor problems were sorted out quite quickly and all the students were able to achieve a successful outcome in the first and second task by the end of the second lesson.

A final problem noted by the teacher was in giving marks for student work as he was unable to get around the room in time.

The teacher also noted many positives in terms of the students' motivation and learning experiences; they appeared to look forward to the lessons in conversations with him and other members of staff and were being very creative in their designs. The teacher also enjoyed listening to the students talking to one another and found they were using specific terminology more such as 'extrude' and 'loft' and were able to describe what these features did. The teacher stated that he believed the strength of the method was in the independence the students had, as they were able to replay the videos or use the help sheet when needed. He believed it had made him more confident and he had begun to take aspects of it to use when teaching other software to the students with 'quite a bit of success'.

One area which failed when delivering the teaching method was that as a test for the final task the teacher stopped the students having access to the video clips, hoping that they would remember how to complete the sequences without help. This was never the intention of the intervention as it is not necessary for students to be able to use the program from memory, only that they develop the confidence to use it and are aware of what it can do, perhaps remembering some of the specific terminology. As the teacher went on to say in the diary, which can be found in Appendix 13, many students wouldn't use the program for another 12 months and it wouldn't be reasonable to expect students to remember every command sequence over this time period, if indeed the program version had not been changed in this time. When use of the video clips was returned to the control of the students, they made more progress, even though the clips did not relate exactly to what they were producing. For example, the students may have been creating a window in the wall of their castle but they would use the video clip showing them how to make coins to do this similar task.

In conclusion, the teacher's view of the program had not changed. However, he could see benefits to the teaching method and would continue to use aspects of it when teaching other programs and he had enjoyed some of the lessons and believed he had developed some confidence.

7.6.2 Teacher interview

The teacher was asked his personal view of using the teaching method. He replied that he had always dreaded using *ProDesktop* as he personally found it difficult to use. Other teachers within the department had stated that they were also reluctant to teach it. When using this resource he found that by lesson 3 he really enjoyed teaching it and was even looking forward to the lessons. He believed that at this point the students were also enjoying the lessons. The teacher gave a few reasons for this, the first being the confidence that the resources gave him. He had enjoyed working through problems with the students and had liked listening to them working through problems themselves using the help sheets that they had been given. In particular he believed the confidence came from not having to say he didn't know how to solve the problem, which had been frustrating for both the teacher and the students, but was able to guide them to be able to work it out themselves. The teacher believed this was a far more valuable learning experience than either not being able to complete tasks or being given the answer as they would be more likely to remember what they had to do next time. One criticism the teacher had of teaching CAD in schools was that he felt that often too much is asked of teachers in that they are expected to pick up and learn new software and then be able to teach it too quickly. Often there isn't the time to do this and for teachers and students alike, sometimes the software is taught for a few weeks and then not needed for a few months, by which time the teachers and students have become a little rusty on the finer points.

The teacher continued that a further advantage to this method of teaching CAD was that there was a scenario. The usual method of teaching CAD is to copy identical objects but students couldn't see the point as they didn't see where it was leading. Much like copying notes from a book. The scenario built up over the weeks and the students were able to express their individuality in their designs. This prevented the students from becoming bored and allowed them to see the task in the wider scheme. When asked whether the students had been able to be creative with their designs the teacher replied, 'Creativity – try gay abandon or rather they abandoned copying the video after about week 3 when they realised they got better marks if their work looked different from it.'

Paired learning was an additional advantage to the teaching method both with and without the videos and the teacher believed it increased the students' confidence to try different things, make mistakes and solve them. The video clips increased this confidence as it had been his experience that students either don't or can't read written instructions. By seeing exactly where the cursor needs to go for example, without much reading, the students were able to follow the instructions. Being able to pause, rewind and play the video clip also helped as the students could revisit parts that had confused them and also see at which point they had gone wrong.

The teacher stated that the students had voiced two problems with the lessons when he spoke to them at the end of the study. The first was that they believed the CAD program should be taught in IT lessons and not Design and Technology lessons. This was not an issue that had been raised by any students at the school where the original study had taken place, and possibly reflects the extent of difference in the quantity of IT use in the two departments. In the original school IT was very much embedded into the Technology classrooms with 6 out of 10 rooms having a class set of computers. When asked how he felt about the students concerns the teacher said that he felt Technology lessons were the practical application of many other subjects like Science, Maths and IT, therefore he believed it was in exactly the right subject and said he was keen to bring lessons within his department into the 21st century. The second problem the students had was that towards the end of the study they became frustrated when they weren't able to perform a command that they wanted on the software. The teacher's personal opinion on this was that he felt this was reflected in the students' answers in the final questionnaire and did not do the study justice. He continued that the students had been enthusiastic up until the point where they were asked to do the castle and had appeared to enjoy the task as well as being able to be creative. The teacher concluded that maybe too much was being asked of students in Year 7 and that the task would have been better if it had stopped before the castle or if it had been used as an extension task for the more able students.

He believed that possibly the knowledge should be built up over a couple of years or more of the basic tasks using the simple commands should be repeated more frequently throughout the game, thereby embedding this knowledge more firmly.

7.6.3 Student opinion and work outcome

In the initial questionnaire 25% of students chose number 1 or 2, indicating that they expected to find the program easy to use and a high percentage of 70% chose 1 or 2 for enjoyment level, indicating that they expected to enjoy using the program. Once the students had completed the programme of study only 5% said they had found the program easy to use, while 35% indicated that they had actually enjoyed using the program. (Figure 7.2 shows the students' work from Study 4B.)

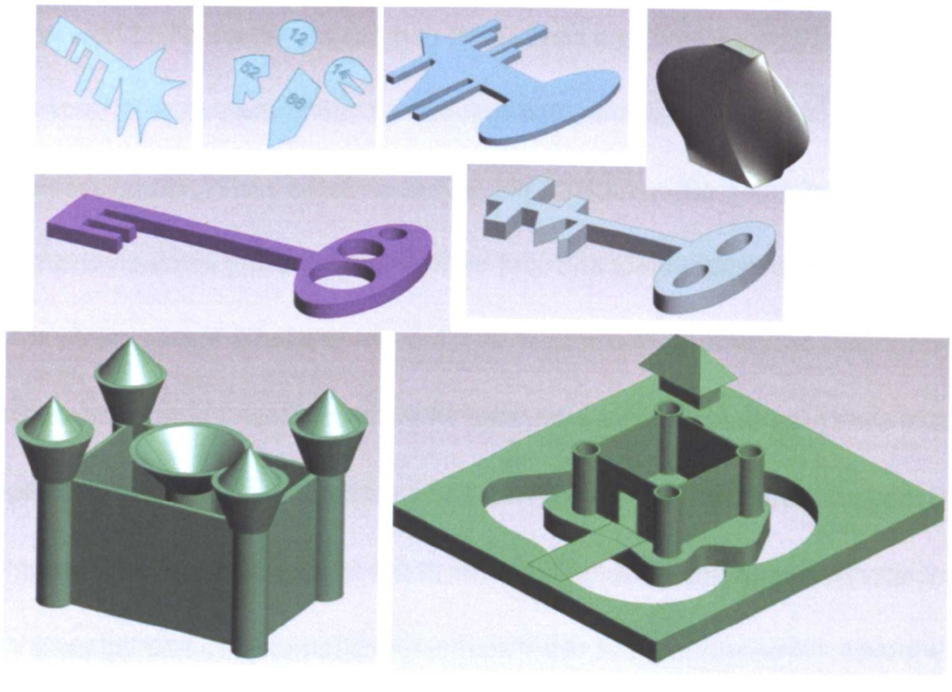


Figure 7.2 Study 4B students' work following intervention trial by a different teacher in a different school

7.7 Reflection on Studies 4A and 4B

In Study 4A and Study 4B both teachers had some similarities and some differences in their experiences and in their teaching practices throughout the teaching method. They both had some issues with the computers themselves, in particular with the presentation of the video clip during the chalice task. This was a problem that had not presented itself in Study 3 probably because of the experience of the teacher involved. Both teachers struggled to get some students to read the instructions at times. Considering a variety of methods to deliver the help sheets such as embedding them into the game or including optional vocal instructions may have helped to improve this; however, it was important to ensure that any additional instructions did not hinder communication between the students which may have made CSCL less effective. Both teachers found the help sheets useful for themselves, reporting that using them gave them confidence when solving problems with the students.

They had both been able to complete the programme of study successfully with both classes producing work not only of a good standard but also showing a good level of creativity. During the post-study interviews one teacher had used the words 'amazed' and the other had been quite vocal when describing how creative they believed the students had been. In Study 4A the teacher reported that the students had appeared to enjoy the more unusual tasks more but had become frustrated if they were unable to achieve the outcome quickly. She stated that in the castle task the students had initially kept to basic designs but were more likely to start again and try more difficult and unique designs. She observed that they didn't appear worried about getting it wrong. She noted, however, that the leap from more structured tasks to such an open brief had appeared to be too much for the students. A similar observation was reported by the teacher in Study 4B who believed that the students had enjoyed each task but had changed their opinion when they reached the castle task. In this study the teacher didn't have the confidence to allow the students the freedom to complete their own design for the castle and had also removed the video clips as support. This had been somewhat disconcerting for the students, however, when the teacher was away so the video clips were reintroduced, and although this enabled the students to achieve the goals set, they appeared to have lost some of their confidence.

Both teachers reported that the students appeared to struggle with some of the basic concepts. In Study 4A the teacher believed the students struggled to understand what a workplane was or how it worked. As workplanes and sketches are a vital aspect of the program this perhaps requires additional explanation within the game. In Study 4B the teacher was concerned that students were unable to remember basic command sequences. Students in this study were able to recognise the various features and were able to find the information they needed to create the feature. The intention of the teaching method is to teach strategic not command knowledge and therefore the students have shown themselves to be successful in this. This observation by the teachers has highlighted that the teaching method could be used in two ways. Firstly, the original intention was that the game should be an introduction to the software and should allow students to explore what *ProDesktop* is capable of so that they know how it could be used at a later stage in their learning. It is possible that the inclusion of the castle task blurs this intention somewhat as it is quite a leap for the students in terms of applying new knowledge. Secondly, the game could be used to teach command sequences but perhaps in older students. In order to achieve this there would need to be much more repetition throughout each of the tasks.

Both teachers had reverted back to their known methods of teaching at times, which although it was not the intention of the study was not detrimental to it. The teacher in Study 4A would have preferred to use the traditional step-by-step approach with a small number of students but still use the video clips to demonstrate. This, however, is likely to be because of the issues with paired learning in the case of this study. The teacher in Study 4B wasn't confident enough to allow the students to fully explore and indicated that he had demonstrated each task, usually on a whiteboard, that he had allocated to the lesson rather than allow the students to work at their own pace. He had also used methods to recap basic commands such as a Martian scenario. Mainly by adopting this hybrid approach both teachers felt more confident. However, in Study 4B the students should have been free to explore; instead of reverting to type by teaching command knowledge the teacher should have persevered with teaching strategic knowledge. As previously stated the resource could be used in this way but not with such young or inexperienced students.

One of the most surprising differences involved CSCL. In Study 4B the teacher found the use of paired learning invaluable. He believed that working in pairs had given the students confidence to try different things and he enjoyed listening to the students problem-solve, which in itself he described as 'a far more valuable learning experience'. He found paired learning so useful when teaching CAD that he adopted the strategy when teaching other CAD software in his school. This experience is similar to that reported in Study 3. The teacher in Study 4A on the other hand had not found paired learning useful and had been disappointed in the way the students in some of the pairings had argued and blamed each other for not helping enough, even though they had been allowed to choose their own pairs. This result is not consistent with Study 3, which had included a much larger sample, or with Study 4B. The teacher in Study 4A had had some positive experiences, however, and stated that if she planned to teach using a similar method again, she would only allow some students to work at their own pace in pairs and would be more prescriptive in the delivery of the programme of study in line with the traditional method of teaching CAD with others. It is difficult to establish on the basis of one study involving such a small number of students whether this difference in experience involving paired learning is due to the dynamics of the class itself, especially as several students had learning difficulties, or whether the teacher struggled with the strategy. Both Cohen (1994) and Chiu (2004) state the importance of level and type of teacher intervention in CSCL as reported in Chapter 2. The teacher in this study suggested that she would prefer to be able to allow some students to work on their own if they could not work with others. While this does not encourage students in the social and emotional aspects of learning or supporting CSCL, producing successful and creative CAD designs is the primary aim of the research; therefore it is reasonable to consider allowing students and teachers the freedom to deliver the resources to suit the student's learning style and class dynamics.

The literature review highlighted in-depth gender differences when learning to use and when using computers. Girls were reported as being less interested in computer activities because of the methods used to teach using computers, which did not appear to suit them. During Study 4A the teacher noted that the girls had achieved better results than the boys. There are two possible reasons for this. Firstly, the game scenario may have suited the girls' style of learning more than the boys', and secondly, the girls may also have enjoyed the communicating aspect of the teaching method, as the teacher also reported that the girls were able to work better together than the boys.

One of the more positive outcomes of this study was the reaction of the instructor in Study 4B. Before the study he had expressed an intense dislike of *ProDesktop* and had never been able to master either using it or teaching it. By the end of the study, not only had his confidence improved but he himself had begun to enjoy the lessons, which was a dramatic change in such a short time. He had stated that he was frustrated that teachers needed to be experts and maintain and update knowledge of a variety of different aspects in Design and Technology, especially in terms of the software used. He believed that this teaching resource removed the need to know everything as it could be used with very little knowledge and it was possible to work through problems with the students. To maintain this it would merely require the software companies to update the resource as and when needed and take the strain off teachers.

Chapter 8 Conclusions

8.1 Conclusions

The aim of this research was to generate new knowledge appropriate to the improved teaching of CAD in the secondary school curriculum. It particularly sought to explore the potential synergy between developing skills and knowledge of CAD and developing creativity in school pupils. It has devised, conducted and evaluated a new approach to the teaching of 3D SMCAD to Key Stage 3 students, specifically focusing on student attitude when using the program, their ability to be able use it and the creative outcome.

The iterative nature of the action research framework that was selected for the intervention study was appropriate to the research because the literature review revealed a foundation of research that was complex with great variety in aims and approaches. This was further complicated by the radical changes in context brought about by recent technological developments. In short, few studies provided suitable starting points because the adoption of CAD technology has progressed so rapidly in schools in recent years. The programme of research was divided into a number of distinct studies, each with their own aims and objectives. The first study – a pilot study – allowed the research questions to become more focused and it highlighted some key problems that Key Stage 3 students face when learning complex 3D SMCAD programs.

One of the potential concerns suggested by the literature review was the nature of spatial awareness exhibited by students and its role in facilitating the learning of CAD. In fact, this relationship had intrigued the author over many years of professional practice in the classroom. Designing with 3D SMCAD involves mentally rotating and holding shapes, as well as working with representations on screen, and it was therefore anticipated that spatial ability would have an effect on students' ability to use the program. Surprisingly spatial ability, examined through a short test and presented in the results of the pilot study and Study 2, appeared to have little effect on students' ability to model using 3D SMCAD or their exhibited creativity. Spatial ability in relation to 3D design warrants consideration in future work, but in this study there was no correlation found between spatial ability and pupil competence to use the given CAD program.

This research has also revealed marked differences to earlier research such as that conducted by Collis (1985), Culley (1988) and Livingstone and Bovill (1999) into motivations and attitudes associated with computer use. Partly this can be put down to a much greater distribution of computer technology and today's widespread accessibility of computers in the home. But there also appears to be distinct differences in pupil attitudes and values between research today and research conducted two decades ago. This study confirmed that more students today have access to a computer at home but more revealing are some of the findings concerning gender. While males and females may still approach computer technology differently, female pupils are now more open to using and interacting with the technology than earlier research indicated. This may be because computer technologies now meet females' needs more readily through social interaction and role-play activities, and this was considered when the various studies reported here were designed. To embrace this, the literature review included studies of CSCW and CSCL such as Webb et al. (1995), Johnson and Johnson (2003), Lipponen et al. (2003) and Terwel (2003). This approach which embraces a computer-mediated learning environment, and which integrates communication and interaction as part of the learning process, has two key advantages: it acknowledges the learning styles of both female and male students, and it offers a clear opportunity to introduce and develop creativity in the classroom.

Another finding revealed by this work is the influence of anticipated enjoyment in the learning of 3D SMCAD. Student participants in the pilot study indicated that they expected to enjoy using the program, but when being taught by the 'traditional method' in Study 2, they appeared to become frustrated and reported decreasing enjoyment as the lessons progressed. The motivational benefit of enjoyment has been widely reported and these studies confirm that poor engagement and low levels of enjoyment have a detrimental effect on the learning of CAD. Comparing student attitudes between the pilot study and Study 2 revealed that if a student *expected* to enjoy using the program then they usually did enjoy using it. What became evident through this section of the study was that student attitude was important for eventual success. Regardless of whether a student had been categorised as a high or low attainer through cognitive assessment testing, the outcome of their CAD models had more to do with whether they *believed* they could achieve a set output and whether they were motivated to use the program. Those students who were high attainers who had also described 3D SMCAD as 'not their cup of tea' or said they didn't enjoy using it, often did not achieve the results expected from their ability level. Equally, however, students who had been judged to have a low attainment level but were enthusiastic about using the program often produced creative and interesting results in their models. Student attitude therefore became a central consideration and continued to be assessed throughout the remaining studies leading to a clear conclusion about the value of strategies that seek to improve student attitude in learning 3D SMCAD. This was founded on numerous earlier studies, revealed through the review of literature, which suggested that nurturing creativity in school-age students is essential. What has been less clear in earlier research is how one integrates the nurturing of creativity in a curriculum area where the pedagogic models for teaching have traditionally focused on the procedural and sequential development of skills and knowledge in CAD. The pilot study confirmed through assessment of the final results that students struggle to produce work that is creative. While some might argue that this might depend on one's definition of the term 'creativity', the curriculum area of Design and Technology has established a fairly clear use for the term to embrace its creative and practical content. In this work creativity was assessed according to National Curriculum benchmark criteria and it led to usable findings regarding whether a particular intervention was able to improve the creative ability of Key Stage 3 students when using 3D SMCAD programs.

It seems clear from this programme of research that a 'command-centred' approach to teaching 3D SMCAD can have a negative effect on learning enjoyment and the development of creativity. While it might facilitate the delivery of some procedural strategies and provide some skills and knowledge it doesn't seem to support the type of deep learning one might expect in a modern classroom. A 'strategic' approach may provide a far superior means of supporting CAD learning through its ability to foster creativity and stimulate enjoyment as well as provide appropriate frameworks for peer communication and the development of CAD skills and knowledge. Many examples of research into different teaching approaches have been carried out with much older university age students, and this work claims to make a contribution to knowledge in the under-researched school age population at Key Stage 3 (11- to 14-year-olds).

The roots of this contribution, discussed in more detail in the following section, are founded on three key questions that were formulated as part of the analysis of the results of the pilot study:

1. Can a more strategic-based intervention improve teaching and learning of 3D SMCAD programs?
2. Can CSCL improve the teaching and learning of 3D SMCAD programs?
3. Can students be helped to achieve more creative outcomes when using 3D SMCAD?

8.2 Key findings and contributions to knowledge

There are five key findings and contributions to new knowledge derived from this research:

1. New pedagogy across teachers and schools.

This section addresses the question can a more strategic-based intervention improve teaching and learning of 3D SMCAD programs? Results from Studies 3 and 4 suggest that the intervention that exploited a strategic approach was far better at enabling the Key Stage 3 students to use 3D SMCAD. Students were able to produce better-quality models that incorporated more features than they had in the previous study, which followed a command-based approach to teaching and learning. More importantly, discussion between the students involved an improved use of technical language and a better understanding of what may make a model fail. The students focused far less on the commands and were more interested in finding out how to create a particular design or design part that they wanted. These results were also reported in both parts of Study 4 where the intervention was delivered by another teacher in the same school (Study 4A); and then also by a different teacher in another school (Study 4B). Study 4B was especially exciting as the teacher was very vocal in saying how much he did not like using or teaching *ProDesktop* before the study began. However, he found the new teaching strategy to be very successful and this had increased his confidence to teach the program. The teacher found the teaching method to be so successful that he has now employed the strategy when teaching other 3D SMCAD programs. It can therefore be concluded that a more strategic-based intervention improves both the teaching and learning of 3D SMCAD programmes.

2. Computer-supported collaborative learning (CSCL)

The second question that emerged from the literature review was can CSCL improve the teaching and learning of 3D SMCAD programs? All three teachers involved in Studies 3 and 4 reported that discussion between students while problem-solving in the tasks included an increased amount of subject-specific terminology, and students had been able to identify features far more easily than previously. Listening to this type of discussion and to students talking about which feature to use and how to make the work more creative was an element that all of the teachers particularly enjoyed. Students stated that their confidence had increased by being able to work together, and most had said during interviews that they liked to work together on the project.

Although one teacher reported concerns with a few of the student–student pairings and suggested that alternative provision should be made for some students, CSCL had been beneficial for a majority of students. It not only improves the teaching and learning of 3D SMCAD to Key Stage 3 students but is a vital element as it allows students to work through problems together and promotes the use of specific terminology in these discussions, which they appear to be able to use and recall more easily than before.

3. Exploration of creativity in practice

The final question explored by the research was whether students could be enabled to be more creative when using 3D SMCAD programs. The most applicable and functional definition of creativity in Design and Technology lessons was of creativity being 'a process involving exploration and evaluation to produce a product that was personally creative'. This definition of creativity was derived from the literature review and also from ways accepted by Design and Technology teachers for assessing creativity in everyday practical situations. In this research, creativity was judged by considering how far the students design varied from the examples they were shown and also through consideration of how basic or complex the shapes used by the students were and in what ways they had developed their design by combining those shapes.

In the first two studies using a command-based teaching method, much of the work produced by each student was similar to that of other students both in the same and in other classes. By being able to discuss and evolve their work using the strategy-based teaching method, however, the work produced as shown in the last two studies was far more varied and personally creative. The discussion the students had while completing the work was much more speculative and adventurous – pupils debating and asking the question 'what if?' which showed that the students were able to self-evaluate and improve their work. Questions to the teacher were more likely to be 'we want to do this' or 'is it possible to do that?' rather than simply asking about the next command as had been the case in the Study 2. Therefore in considering the third question, one may conclude that it is possible to improve the creative outcome of work produced by Key Stage 3 pupils when using 3D SMCAD programs by combining a strategic-based teaching method, CSCL and a range of resources that allow more independence and a focus on how to solve problems.

4. New resources

The intervention developed through these studies has been packaged as a game and trialled with students learning 3D SMCAD programs. This game development has been of interest to DATA (the Design and Technology Association) and to the Education Programme Manager of PTC, the makers of *ProDesktop* and *Creo Elements Pro*. This resource is to become available to all teachers to aid their teaching in schools and to support teachers' professional development. To remain a success, the resources would need to be updated as new versions of the program are produced.

5. Attitudes to computer use

This research has highlighted a significant shift in attitudes to using computers both at home and at school. By comparing the results of this study to one undertaken by Livingstone and Bovill in 1999, more students now have access to a computer at home than they had before and more importantly gender makes much less of a difference in the attitude to computer use than it had done previously. In the literature review Clegg and Trayhurn (1999) are quoted as saying that the question that should be asked is 'what is wrong with computing?' not 'what is wrong with women?' While this former problem with the way computers are used by both genders seems to have been addressed since their research was published, the broader issues of motivation, anticipation and enjoyment are still neglected – particularly in the learning of CAD. It would seem there are major opportunities for research that explored the CSCL of CAD as well as teaching-focused strategies.

Surprisingly, despite the students producing better models and teachers involved in the studies reporting increased enthusiasm by the students, the results show that the students' enjoyment of using *ProDesktop* had not increased. It is likely that this discrepancy in the results versus observation is because of a difference of viewpoint. In terms of enjoyment, would the students enjoy playing a game at home more than an educational game at school? Almost certainly they would. From a teacher's viewpoint, however, the students were engaged in the activity and discussion between the students from this view implied that the students had enjoyed the strategic teaching method. What is important in the results of the studies is that the students were engaged in the activities even if they did not believe that they were enjoying the learning process more; and that the students displayed a far greater confidence both when using the program and in helping each other. The results show that there was a positive shift in student attitude.

8.3 Future work

Investigation of spatial ability and the different types of computer use by students, which were highlighted by the literature review, were not included in the program of research, as other aspects were considered to be more relevant to this particular study. In future studies these issues may be more pertinent.

A further consideration for future work is an investigation into the effect that this strategic method of teaching has on the student's ability and attitude to using 3D SMCAD as they continue through their education. Through observation the researcher has noted that the students involved in Studies 1 and 2, who had then been taught using the new pedagogy the following year (Year 8 students in Study 3) and are now Key Stage 4 students, choose to use 3D SMCAD programs more frequently, even when it is not necessarily appropriate to the task. The students appear to be more confident in using the program, are certainly more likely to try and help each other and seem to adapt to more updated versions of 3D SMCAD programs. This has been particularly noted between PTC's *ProDesktop* and *Creo Elements Pro*. Both programs use the same terminology and similar errors will make the model fail but are otherwise very different. This raises various questions such as *why* are the students more likely to choose 3D SMCAD instead of hand-drawing techniques. Are the students actually more confident when using 3D SMCAD and are the students more able to adapt to updated versions of the 3D SMCAD software?

On a personal level, the new pedagogy has improved the author's teaching practice by removing the tedium of repeatedly emphasising commands in lessons and allowing for a more exploratory approach. Through listening to the dialogue during the use of CSCL and providing praise for taking risks and trying different strategies, the students are able to learn and achieve new understanding of what is possible – even if the resulting model fails – because the approach is much more suited to helping students recognise the cause of errors. From the teacher's point of view, they are able to provide assessment which meets Government requirements while allowing personalised feedback and the encouragement of creative exploration. Assessment requirements are not stifling creativity. Guiding students to create their own unique designs and seeing the students achieve difficult outcomes is certainly more rewarding than a class full of students each producing the same design by following a rigid set of instructions. Teachers other than the researcher have benefited by not having to be an 'expert' at the program; they are able to work through problems with the student and this has given them the confidence to allow the student to take risks and try new things. This benefit has also been recognised by the instructors, provided by the Design and Technology Association, who believe the resource to be valuable. As one of the *ProDesktop* instructors said, 'I am sure that this is a project that will have enormous benefits in schools.'

It is clear that ICT will continue to play an increasingly pivotal role in the education policies of developed and developing countries. Its core role at all levels, including secondary schools is assured. David Puttnam, Lord Puttnam of Queensgate, in his 'Opening Keynote' at the Innovating e-Learning 2011 conference, argued for greater investment in ICT to enable UK universities, colleges and schools to deliver a world-class education: 'Digital technology is the driving force behind change. We cannot afford not to invest in it' (Puttnam, 2011).

Paradoxically, the ubiquitous distribution of ICT in today's schools has led to a greater rather than a reduced necessity for research. Nowhere is the need greater than in the Design and Technology curriculum area. This is an area whose lifeblood is the development and demonstration of creativity and innovation. We have an unprecedented opportunity to meld the development of creativity with computer-aided design but the future systems for achieving this depend on sensitive research by those who can interpret the needs in the classroom.

References

Ahn, H.J. (2005) 'Child care teachers' strategies in children's socialization of emotion', *Early Child Development and Care*, no. 175, pp. 49–61.

Amabile T.M. (1996) *The Social Psychology of Creativity*, New York, Springer-Verlag.

American Association of University Women Education Foundation (AAUW) (2000) *Tech-savvy: Educating Girls in the New Computer Age*, USA, AAUW.

Armstrong, A., and Casement, C. (2000) *The Child and the Machine: How Computers Put Our Children's Education at Risk*, Beltsville, MD, Robins Lane Press.

Banaji, S, Burn, A and Buckingham, D. (2010) Rhetorics of creativity: a literature review. *Creativity, Culture and Education*. Newcastle-upon-Tynne.

Bandura, A. (1997) *Self-efficacy: The Exercise of Control*, New York, W.H. Freeman.

Bandura, A. (2001). Social cognitive theory: An Agentic Perspective. *Annual Review of Psychology* Vol. 52. pp 1-26.

Barbieri, M. and Light, P. (1992) Interaction, gender and performance on a computer-based task. Learning and Instruction vol. 2, pp 199-213

Best, B. and Thomas, W. (2007) *The Creative Teaching and Learning Toolkit*, London, UK, Continuum International.

Bhavnani, S., Garrett, J. and Shaw, D. (1993) 'Leading indicators of CAD experience', CAAD Futures '93, pp 313-334.

Boden, M. (2004) *The Creative Mind: Myths and Mechanisms*, London, Routledge.

Bowkett, S. (2005) *100 Ideas for Teaching Creativity*, London, UK, Continuum.

Buckingham, D. (2007) *Beyond Technology: Children's Learning in the Age of Digital Culture*, Cambridge, UK, and Malden, USA, Polity Press.

Carbonaro, M., Szafron, D., Cutumisu, M. and Schaeffer, J. (2010) Computer game construction: a gender neutral attractor to computer science, *Computers and Education*, vol. 55, no. 3, pp. 1098–111.

Carter, J. (2010) 'What are the important gender-related issues in computing at present?', Editorial, *Computer Science Education*, vol. 20, no. 4, pp. 261–3.

Chen, M. and Armstrong, S. (eds) (2002) *Edutopia: Success Stories for Learning in the Digital Age*, San Francisco, Jossey-Bass.

Chester, I. (2007) 'Teaching for CAD expertise', *International Journal of Technology Design Education*, no. 17, pp. 23–35.

Chiu, M.M. (2004) 'Adapting teacher intervention to student needs during co-operative learning: how to improve student problem solving and time on task', *American Educational Research Journal*, vol. 41, no. 2. pp 365-400

Clegg, S. and Trayhurn, D. (1999) 'Gender and computing: not the same old problem', *British Educational Research Journal*, vol. 26, no. 1. pp75-89

Cohen, E.G. (1994) 'Restructuring the classroom: conditions or productive small groups', *Review of Educational Research*, no. 64, pp. 1–35.

Cohen, L.M. (2011) 'Adaptation, adaptiveness, and creativity', in Runco, R. and Pritzker, S. (eds) (2011) *Encyclopedia of Creativity*, 2nd edn, San Diego, CA, Elsevier, pp. 9–17.

Collis, B. (1985) 'Sex-related differences in attitudes toward computers: implications and counsellors', *School Counsellor*, vol. 33, no. 2, pp. 120–30.

Cooper, J. (2006) 'The digital divide: the special case of gender', *Journal of Computer Assisted Learning*, vol. 22, pp. 320–34.

Cordes, C. and Miller, E. (2000) *Fools' Gold: A Critical Look at Computers in Childhood* [online], Maryland: Alliance for Childhood, http://www.allianceforchildhood.net (Accessed 13th September 2008)

Cox G, (2005) *Cox Review of Creativity in Business: Building on the UK's Strengths*, London, HM Treasury [online], http://www.hm-treasury.gov.uk/cox_review_creativity_business.html (Accessed 10th April 2008).

Craft, A. (2005) *Creativity in Schools: Tensions and Dilemmas*, London Routledge.

Cropley, A.J. (2001) *Creativity in Education and Learning*, London, Kogan Page Limited.

Csikszentmilhalyi, M. (1996) *Creativity: Flow and the Psychology of Discovery and Invention*, New York, Harper Collins.

Culley, L. (1988) 'Girls, boys and computers', *Educational Studies*, vol. 14, no. 1, pp. 3–8.

De Bono, E. (1985) *Six Thinking Hats*, Boston Little, Brown and Company.

Department for Education (DfE), QCA (1999) *Design and Technology: The National Curriculum for England*, London, HMSO.

Department for Education (DfE), QCA (2007) Design and Technology: The National Curriculum for England, London, HMSO.

Department for Education (DfE), QCA (2002) *key stage 3 National Strategy*, London, HMSO.

Department for Education (DfE) (2003) *Every Child Matters*, London, TSO HMSO.

Diakidoy, I.-A.N. and Kanari, E. (1999) Student teachers' beliefs about creativity, *British Educational Research Journal*, vol. 25, no. 2. pp 225-243

Fisch, K. and Mcleod, S. (2007) Shift Happens [online], http://www.teachertube.com/view_video.php?viewkey=bbf824c98a1278ffadc2-66k (Accessed 11th November 2007).

Gardner, H. (1993) *Frames of Mind: The Theory of Multiple Intelligences*, New York, Basic Books.

Gates, B. (1995) *The Road Ahead*, London, Viking, p. 212.

Gaughran, W. F. (2002). Cognitive modeling for engineers. American Society for Engineering Education Annual Conference and Exposition conference proceedings. American Society for Engineering Education.

Gillies, R.M. and Ashman, A.F. (eds) (2003) *Cooperative Learning: The Social and Intellectual Outcomes of Learning in Groups*, London and New York, Routledge Falmer.

Guzdial, M. and Turns, J. (2000) 'Effective discussion through a computer-mediated anchored forum', *Journal of the Learning Sciences*, no. 9, pp. 437–69.

Healy, J. (1998) *Failure to Connect: How Computers Affect Our Children's Minds for Better and Worse*, New York, Simon and Schuster.

Heider, F. (1958) *The Psychology of Interpersonal Relations*, New York, John Wiley & Sons.

Hermer-Vasquez, L., Moffet, A. and Munkholm, P. (2001) 'Language, space, and the development of cognitive flexibility in humans: the case of two spatial memory tasks', *Cognition*, no. 79, pp. 263–81.

Hodgson, T. and Allsop, C. (2003) *Beyond Pro/DESKTOP Computer Aided Design (CAD): The Transfer of CAD-based Design Modelling Skills From Schools to Higher Education*, Wellesbourne, DATA.

Hunter, S.T., Bedell, K.E. and Mumford, M.D. (2007) 'Climate for creativity: a quantitative review', *Creativity Research Journal*, vol. 19, no. 1, pp. 69–90.

Illich, I. (1971) *Deschooling Society*, Harmondsworth, Penguin.

Isaksen, S.G., Lauer, K.J., Ekvall, G. and Britz, A. (2001) 'Perceptions of the best and worst climates for creativity: preliminary validation evidence for the Situational Outlook Questionnaire', *Creativity Research Journal*, no. 13, pp. 171–84.

Johnson, B. and Christensen, L. (2008) *Educational Research – Quantitative, Qualitative, and Mixed Approaches*, Los Angeles, Sage.

Johnson, D.W. and Johnson, R.T. (2003) 'Student motivation in co-operative groups. Social interdependence theory', in Gillies and Ashman (eds) (2003), pp. 136–76.

Jorum, E., Woodruff, E., Bryson, M. and Lindsay, P. (1992) 'The effects of revising with a word processor on writing composition', *Research in the Teaching of English*, vol. 26, no. 2, pp. 167–92.

Kaufman, J.C. (2002) 'Creativity and confidence: price of achievement?', *American Psychologist*, vol. 57, pp. 375–6.

Kennewell, S., Parkinson, J. and Tanner, H. (2003) *Learning to Teach ICT in the Secondary* School, London, RoutledgeFalmer.

Khatoon, T. and Mahmood, S. (2011) 'Computer attitude as a function of gender, type of school mathematics anxiety and mathematics achievement', *European Journal of Social Sciences*, vol. 18, no. 3. pp.434-443

Kimbell, R. (2000) 'Creativity in crisis', *Journal of Design and Technology Education*, vol. 5, no. 3, pp. 206–11.

Kress, G. (2000) 'A curriculum for the future', *Cambridge Journal of Education*, vol. 30, no. 1, pp. 133–45.

Lang, G.T., Eberts, R.T., Gabel, M.G. and Barash, M.M. (1991) 'Extracting and using procedural knowledge in a CAD task', *IEEE Transactions on Engineering Management*, no. 38, pp. 257–68.

Leitch, M. (2003) 'A new approach to stress management, why uncertainty causes stress, and how to stop it'. [online], http://www.managedluck.co.uk/stress/ (accessed 15th November 2007)

Likert, R. (1932) 'A technique for the measurement of attitudes', *Archives of Psychology*, no. 140. pp 5-53

Lipponen, L., Rahikainen, M., Lallilmo, J. and Hakkarainen, K. (2003) 'Patterns of participation and discourse in elementary students' computer-supported collaborative learning', *Learning and Instruction*, no. 13, pp. 487–509.

Livingstone, S. and Bober, M. (2005) *UK Children Go Online: Final Report of Key Project Findings*, London, London School of Economics and Political Science.

Livingstone, S. and Bovill, M. (1999) *Young People, New Media*, London, London School of Economics and Political Science.

Lucas, B. (2001) 'Creative teaching, teaching creativity and creative learning', in Craft, A., Jeffrey, B. and Liebling, M. (eds) (2001) *Creativity in Education*, London, Continuum, pp. 35–44.

Macintyre, C. (2000) *The Art of Action Research in the Classroom*, London, David Fulton Publishers.

Marsh, J. (2010) 'Childhood, culture and creativity: a literature review', *Creativity, Culture and Education*. Newcastle upon Tyne: Creativity, Culture and Education.

McCarthy, B. (1972, revised 1980) *The 4MAT System: Teaching to Learning Styles with Right/Left Mode Techniques*, revised edn, Oak Brook, IL, Excel, Inc.

McLellan, R., & Nicholl, B. (2008). *The importance of classroom climate in fostering student creativity in design & technology lessons.* In E. W. L. Norman & D. Spendlove (Eds.), Designing the curriculum–making it work: The design and technology association international research conference 2007 (pp. 29–35). Telford: Loughborough University.

Meloth, M.S. and Deering, P.D. (1999) 'The role of the teacher in promoting cognitive processing during collaborative learning', in O'Donnell, A.M. and King, A. (eds) (1999) *Cognitive Perspectives on Peer Learning*, Mahwah, NJ, Erlbaum, pp. 235–55.

Michael K. (2001) 'The effect of computer simulation activity versus a hands-on activity on product creativity in Design and Technology', *Journal of Technology Education*, no. 13, pp. 31–43.

Mukherji, P. and Albon, D. (2010) *Research Methods in Early Childhood*, London, Sage.

Musta'amal, A.H., Norman, E.W.L. and Hodgson, T. (2008) *CAD as a 'Recording' or 'Designing' Tool: Evidence from User Behaviours*, IN: Norman, E.W.L. and Spendlove, D. (eds.). The Design and Technology Association International Research Conference, [Loughborough University, 2-4 July]. Wellesbourne : The Design and Technology Association, pp. 47-54

Musta'amal, A.H., Norman, E.W.L. and Hodgson T. (2009) 'Gathering empirical evidence concerning links between computer aided design (CAD) and creativity', *Design and Technology Education: An International Journal*, vol. 14, pp. 53–66.

National Advisory Committee on Creative and Cultural Education (NACCCE) (1999) *All Our Futures: Creativity, Culture and Education*, London, DfE.

Ofsted. (2002) *ICT in Schools: Effect of Government Initiatives Secondary Design and Technology HMI 701*, London, HMI

Ofsted (2004) *ICT in Schools: Effect of Government Initiatives Secondary Design and Technology HMI 2192*, London, HMI

Parker, J. (2003). 'Weaknesses revealed.' In D. Barlex (Ed.), Creativity in crisis? Design & technology in KS3 and KS4 6-8. London: Nuffield Foundation.

Papert, S. (1993) *Mindstorms: Children, Computers and Powerful Ideas*, New York, Basic Books.

Pektas, S.T. and Erkip, F. (2006) 'Attitudes of design students toward computer usage in design', *International Journal of Technology and Design Education*, no. 16, vol. 1, pp. 79–95.

Prinsen, F.R, Volman, M.L.L. and Terwel, J. (2007) 'Gender-related differences in computer-mediated communication and computer-supported collaborative learning', Journal of Computer Assisted Learning. *International Journal of Teaching and Learning in Higher Education*. Volume 19, No 2, pp. 105-116

Puttnam, D. (2011) Opening Keynote, 'Innovating e-Learning 2011: Learning in transition', *sixth JISC Online Conference*, November [online], http://elearning.jiscinvolve.org/wp/2011/11/ (20th December 2011).

Robinson, K. (2001) *Out of Our Minds: Learning to be Creative*, Oxford, Capstone.

Robinson S. (2007) 'Abandon the script, then we can have some real dialogue', *Times Educational Supplement*, December.

Robson, C. (1993) *Real World Research: A Resource for Social Scientists and Practitioner Researchers*, Cambridge, MA, Blakewell.

Rutland, M. and Barlex, D. (2008) 'Perspectives on pupil creativity in design and technology in the lower secondary curriculum in England', International Journal of Technology and Design Education, vol. 18, issue 2, March, pp. 139–65.

Rynne, A., & Gaughran, W. (2007). Cognitive modelling strategies for optimum design intent in parametric modelling. *Proceedings of American Society for Engineering Education Annual Conference & Exposition.* Honolulu, Hawaii, June

Seltzer, K. and Bentley, T. (1999) *The Creative Age: Knowledge and Skills of the New Economy*, London, Demos.

Sheingold, K. and Hadley, M. (1990) *Accomplished Teachers: Integrating Computers into Classroom Practice,* New York, Center for Technology in Education, Bank Street College of Education.

Siann, G. (1997) 'We can, but we don't want to: factors influencing women's participation in computing', in Lander, R. and Adam, A. (eds) (1997) *Women in Computing*, Exeter, Intellect.

Smith, A. (2007) *Accelerated Learning in the Classroom*, London Network Educational Press.

Smith, S.D. (1986) 'Relationships of computer attitudes to sex, grade level and teacher influence', *Education*, vol. 106, issue 3, Spring, pp. 338-344

Spendlove, D., (2007) 'The locating of emotion within a creative, learning and profit orientated design and technology experience: person, process, product', *International Journal of Technology and Design Education*, no. 18, pp. 45–57.

Squires, D. and McDougall, S. (1994) *Choosing and Using Educational Software: A Teachers' Guide*, London, Falmer Press.

Stein, M. (1953) 'Creativity and culture', *Journal of Psychology*, no. 36, pp. 311–22.

Sternberg, R.J. (1985) *Beyond IQ: A Triarchic Theory of Human Intelligence*, New York, Cambridge University Press.

Sternberg, R. and Grigorenko, E. (1997) 'Are cognitive styles still in?', *American Psychologist*, vol. 52, no. 7, pp. 700–12.

Stoilescu, D. and Egodawatte, G. (2010) 'Gender differences in the use of computers, programming, and peer interactions', *Computer Science Education*, vol. 20, no. 4, pp. 283–300.

Szymanski, K. and Harkins, S.G. (1992) 'Self-evaluation and creativity', *Personality and Social Psychology*, vol. 18, pp. 259–65.

Terwel, J. (2003) 'Cooperative learning in secondary education: a curriculum perspective', in Gillies and Ashman (eds) (2003), pp. 54–68.

Turkle, S. (1984) *The Second Self: Computers and the Human Spirit*, New York, Simon and Schuster.

Twining P. (2002) 'Conceptualising computer use in education: introducing the computer practice framework (CPF)', *British Educational Research Journal*, vol. 28, no. 1. pp. 95-110

Underwood, J., Smith, L., Uckin, R.and Fitzpatrick, G. (2008) 'E-Science in the classroom – towards viability', *Computers & Education Journal*, vol. 50, no. 2, pp. 535–46.

Uzun, A. and Sengal, E. (2009) 'Attitudes of students towards computers', *E-Journal of New World Science Academy*, vol. 4, no. 3. pp. 797-805

Valentine, G. and Holloway, S. (2001) 'Technophobia', in Hutchby, I. and Moran-Ellis, J. (eds) (2001) *Children, Technology and Culture: The Impacts of Technologies in Children's Everyday Lives*, London, RoutledgeFalmer, pp. 58–77.

Volman, M. and van Eck, E. (2001) 'Gender equity and information technology in education. The second decade', *Review of Educational Research*, vol. 71, no. 4, pp. 613–31.

Walliman, N.S.R. (2001) *Your Research Project: A Step by Step Guide for the First-time Researcher*, London, Sage.

Webb, N.M., Troper, J.D. and Fall, R. (1995) 'Constructive activity and learning in collaborative small groups', *Journal of Educational Psychology*, vol. 87, no.3, pp. 406–23.

Williams, D., Wilson, K., Richardson, A., Tuson, J. and Coles, L. (1998) *Teachers' ICT Skills and Knowledge Needs: Final Report to SOEID* [online], http://www.scotland.gov.uk/library/ict (Accessed 2nd July 2007).

Willoughby, T., Wood, E., Desjarlais, M., Williams, L., Leacy, K. and Sedore, L. (2009) 'Social interaction during computer based activities', *Sex Roles: A Journal of Research*, vol. 61, no. 11/12, pp. 864–78.

Appendices

Appendix 1 Questionnaire used in Study 1

First name Surname male/female

1. Have you used 3D CAD software before yes/no

2. How many hours if any do you use a computer in a week (include both fun and work use)

0 5 10 15 20 25 more

3. Do you have a computer you can use at home? yes/no

4. On a scale of 1 to 5 how hard do you think using 2D design will be?

not very hard 1 2 3 4 5 hard

5. Do you think you will enjoy using 2D design?

enjoy 1 2 3 4 5 will not enjoy

6. Do you think you would enjoy using 2D design more/the same/or less if you didn't make a product? Circle your chosen answer.

more the same less

7. On a scale of 1 to 5 how hard do you think using ProDesktop will be?

easy 1 2 3 4 5 hard

8. Do you think you will enjoy using ProDesktop?

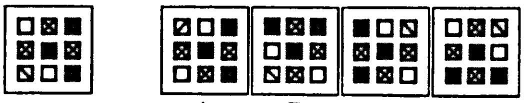
enjoy 1 2 3 4 5 will not enjoy

Appendix 2 Spatial awareness test used in Study 1

Spatial Ability – Practice Test 1

In the figures shown below, one of the shapes (A-D) is identical to the first figure but has been rotated.

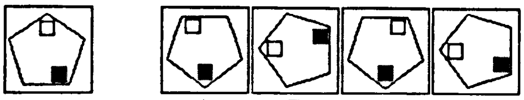
26) Which figure is identical to the first?



A B C D

A B C D

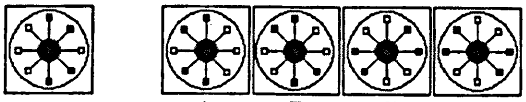
27) Which figure is identical to the first?



A B C D

A B C D

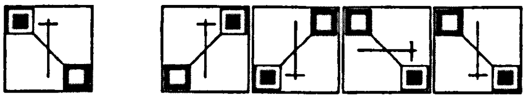
28) Which figure is identical to the first?



A B C D

A B C D

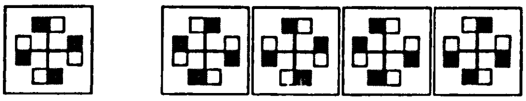
29) Which figure is identical to the first?



A B C D

A B C D

30) Which figure is identical to the first?



A B C D

A B C D

Appendix 3 Questionnaire used at the start of Studies 2, 3 and 4

First Name ____________ Surname_________________

1. On a scale of 1 to 5 how hard do you think you will find using ProDesktop?

easy 1 2 3 4 5 hard

2. How much do you think you will enjoy using ProDesktop?

enjoy 1 2 3 4 5 will not enjoy

3.Why do you think you felt this way?

Appendix 4 Questionnaire used at the end of Study 2

First Name ____________ Surname_________________

1. On a scale of 1 to 5 how hard did you find using ProDesktop?

easy 1 2 3 4 5 hard

2. How much did you enjoy using ProDesktop?

enjoy 1 2 3 4 5 will not enjoy

3.Why do you think you felt this way?

Appendix 5 Questionnaire used at the end of Studies 3 and 4

First Name ____________ Surname_________________

1. On a scale of 1 to 5 how hard did you find using ProDesktop?

easy 1 2 3 4 5 hard

2. How much did you enjoy using ProDesktop?

enjoy 1 2 3 4 5 will not enjoy

3.Why do you think you felt this way?

4. How did you feel about working in pairs?

5. Did the video clips help you use Prodesktop?

6. Did the game or the competition help you to try harder when learning ProDesktop?

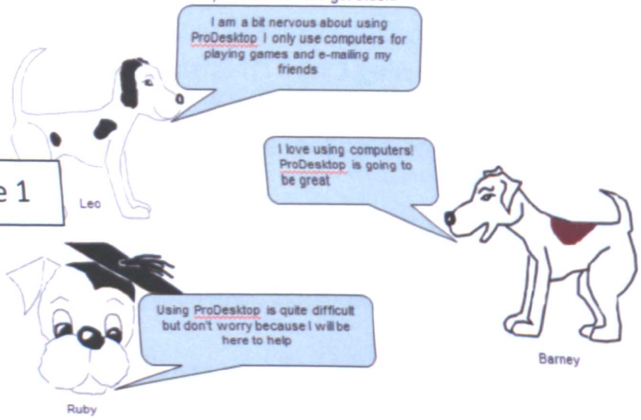
Appendix 6 Questions used in the semi-structured interviews in Study 2

1. Why do you feel the way you do about using CAD? (This was the same regardless of whether the students were positive or negative about their experiences.)
   As the interviewer is familiar with the tasks and has a positive experience with the use of CAD it is important that these views were not expressed and did not influence the discussion; however, the discussion needed to be prompted at times to provide more in-depth information.
2. Do you think that working in pairs would be beneficial to you?
   This question aimed to determine if the students felt that computer-supported collaborative learning (CSCL), also identified in the literature review, would help them to enjoy and/or use CAD more effectively.
3. Students were shown a resource involving some characters that they could work with independently (Appendix 6). The students were then asked whether they thought something like the resource would help them to learn CAD.
4. What do you think creativity is? This question aims to help students answer question 5 and establishes if students have an understanding of creativity.
5. Do you think your work was creative?
6. What do you think helped or prevented you from being creative?
7. Finally the students were asked if there was anything else they wanted to add.

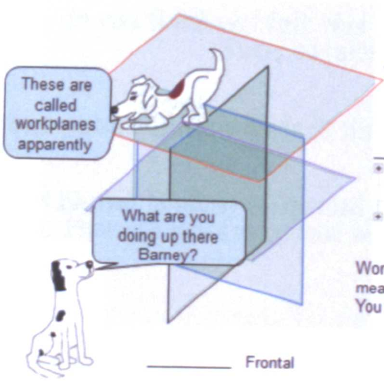
Appendix 7 Intended intervention for Study 3

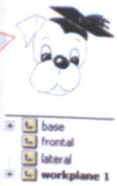
Meet Leo and Barney, they are going to be learning ProDesktop. Leo is a bit nervous and thinks it's going to be hard. Barney is looking forward to using it but tends to forget to use the instructions and then gets stuck and doesn't know what to do. Ruby, the professor is going to help them when the get stuck.

Page 1



Before they can begin there are lots of new words to learn like **Workplane**...





Professor Ruby says that workplanes are the surfaces that you can draw on. Much like pieces of paper. When you open a new design you already have three workplanes to choose from called Base, Frontal and Lateral. These are shown on the left side of the screen in a browser. Any new workplanes you make are either numbered like the example to the left or you can name them to help you find them easily.

Page 2

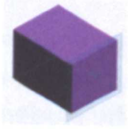
Workplanes are usually on a surface or can be offset which means they are suspended above the original workplane. You can offset a workplane from any existing workplane.

Frontal

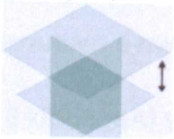
Lateral

Base (This is the one you start working on)

Workplane 1

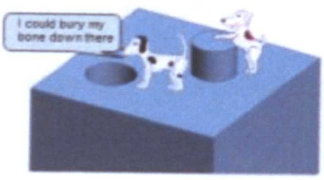


Surface workplane



Offset

...Sketch...



Professor Ruby says a feature is something you do to make things look 3D. We will look at these soon but for now all you need to remember is that for every new feature you want will need a new sketch on your workplane. For example if you want two buttons the same height but different sizes you can use the same sketch. If you want a button and a hole you can use the same workplane but will need a new sketch.

Page 3

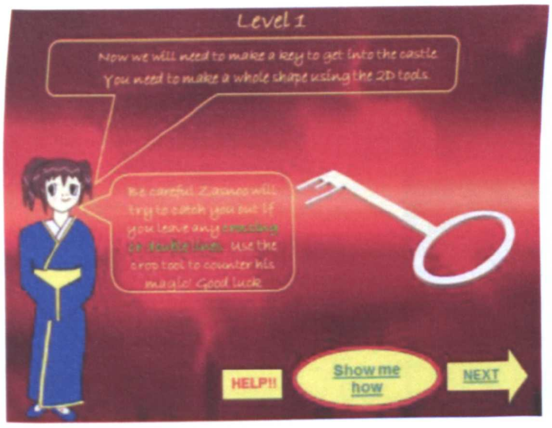
These are the sketches for this model. They are named to make it easier to find. If I was to start drawing now I would be drawing on the sketch called button. Anything I draw on this sketch will end up the same height as the button on the model

Like the workplanes the sketches are shown in the left hand browser and you can name them to make it easier to find later. The one you are currently working on is shown in bold lettering.

! If a model isn't working check to make sure you are working on the sketch you think you are.

It is important you know which sketch you are working on although it is easy to change the sketch you are working on by left clicking on the sketch in the browser then right clicking and selecting activate sketch

Appendix 8 Actual intervention in Studies 3 and 4

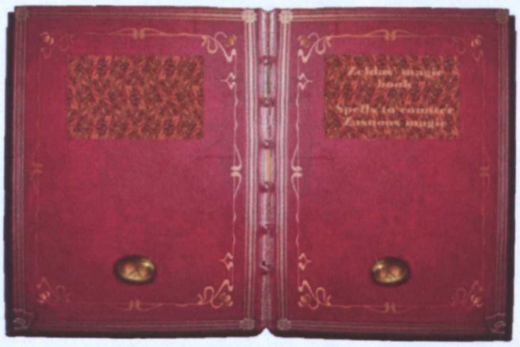


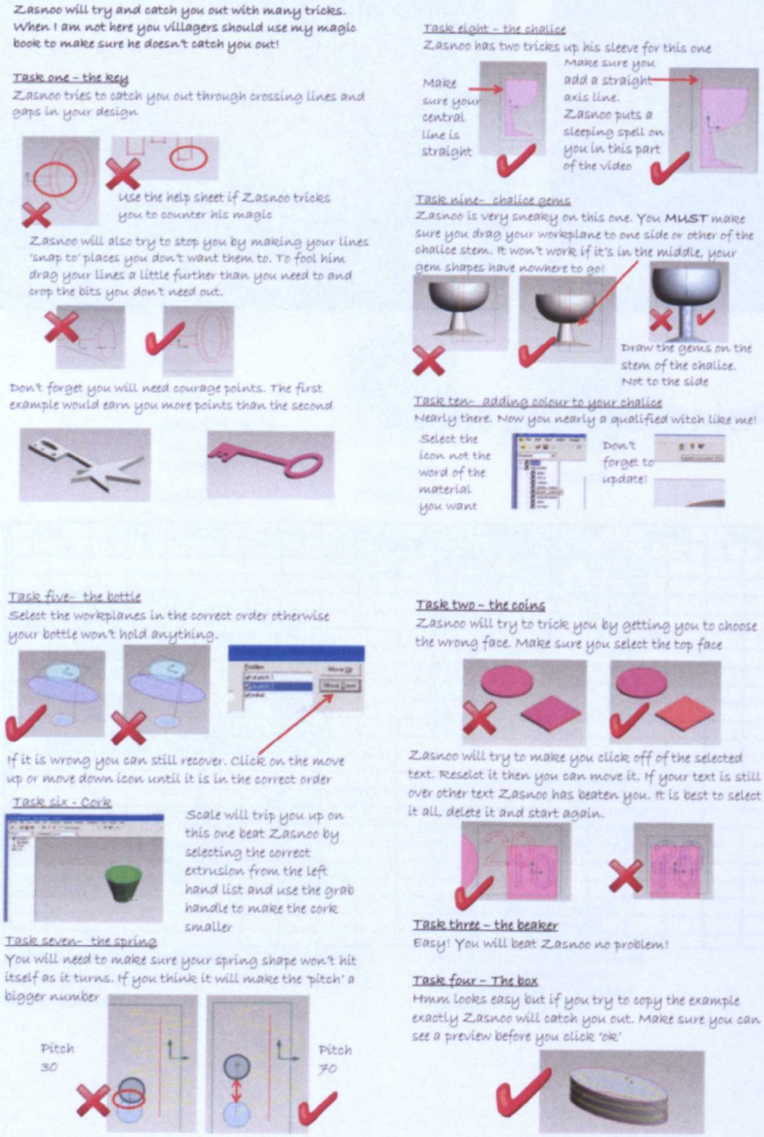
Appendix 9 Points scoring sheet

Names	Key		Coins		Beaker		Box		Bottle		Cork		Chalice		Gems		Spring		Colour		Castle	
	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C

Appendix 10 Help sheet used with intervention

Presented as a book of spells to the students





Zasnoo will try and catch you out with many tricks. When I am not here you villagers should use my magic book to make sure he doesn't catch you out!

Task one – the key

Zasnoo tries to catch you out through crossing lines and gaps in your design

Use the help sheet if Zasnoo tricks you to counter his magic

Zasnoo will also try to stop you by making your lines 'snap to' places you don't want them to. To fool him drag your lines a little further than you need to and crop the bits you don't need out.

Don't forget you will need courage points. The first example would earn you more points than the second

Task eight – the chalice

Zasnoo has two tricks up his sleeve for this one

Make sure your central line is straight

Make sure you add a straight axis line. Zasnoo puts a sleeping spell on you in this part of the video

Task nine- chalice gems

Zasnoo is very sneaky on this one. You **MUST** make sure you drag your workplane to one side or other of the chalice stem. It won't work if it's in the middle, your gem shapes have nowhere to go!

Draw the gems on the stem of the chalice. Not to the side

Task ten- adding colour to your chalice

Nearly there. Now you nearly a qualified witch like me!

Select the icon not the word of the material you want

Don't forget to update!

Task five- the bottle

Select the workplanes in the correct order otherwise your bottle won't hold anything.

If it is wrong you can still recover. Click on the move up or move down icon until it is in the correct order

Task six - Cork

Scale will trip you up on this one beat Zasnoo by selecting the correct extrusion from the left hand list and use the grab handle to make the cork smaller

Task seven- the spring

You will need to make sure your spring shape won't hit itself as it turns. If you think it will make the 'pitch' a bigger number

Pitch 30

Pitch 70

Task two – the coins

Zasnoo will try to trick you by getting you to choose the wrong face. Make sure you select the top face

Zasnoo will try to make you click off of the selected text. Reselct it then you can move it. If your text is still over other text Zasnoo has beaten you. It is best to select it all, delete it and start again.

Task three – the beaker

Easy! You will beat Zasnoo no problem!

Task four – The box

Hmm looks easy but if you try to copy the example exactly Zasnoo will catch you out. Make sure you can see a preview before you click 'ok'

Appendix 11 Questions used in the semi-structured interviews in Study 3

1. Why did you feel the way you did about using CAD?

   The intention of this question was to determine whether issues highlighted in the first set of interviews had been addressed by the intervention or whether any new concerns had arisen because of it.

2. How did you feel about working in pairs? This intended to gain further insight into whether CSCL had been successful in addressing any issues relating to learning CAD.

3. Were the video clips help when learning ProDesktop?

   This was asked to determine whether the clips had allowed pupils to work more independently at their own pace or not and if this had helped the students when learning CAD.

4. Did you enjoy the game aspect of learning CAD?

5. What do you think creativity is?

6. Do you think your work is creative?

7. Finally the students were asked if there was anything they would like to add.

Appendix 12 Teacher diary – Study 4A

Lesson 1

When I started with this group they had already completed their questionnaire and had been made aware of the way the game works. I allowed the students to choose their own partner as I was unfamiliar with the group and thought that if they chose their own partner they would work better together than if I chose for them. The students did this quite quickly and then logged on. As it was the first time they had needed to turn the graphics hardware acceleration off I read this out to them and they all completed it together with the exception of one student who had an issue logging on and was behind. The students started the first task which was to make a key shape and extrude it. Most did well at this with only a few not noticing that they had to cut out a section of the key or had drawn over the line a couple of times. With some prompting they were able to work out what they needed to do and by the end of the lesson all students had made a key and some had been able to make a more unusual design. I found the help sheet useful in this as I was able to see what the problem was myself and could direct students to the right instructions.

Lesson 2

The instructions of how to get onto the two programs were clearly written on the board and I went through them all. I made very specific reference to the command sequence needed to turn the graphics off in order to get the *ProDesktop* program working. Most students were able to use these successfully to help them open the programs and start the task. Some students, however, were unable to follow the written instructions which would suggest that they are either struggling with literacy or are simply lazy (the latter being the case of the child who said he couldn't read it because the light was shining on it). A few students had not done the sequence of tools, options, performance as requested and therefore their computers were not responding properly.

I had mixed feelings at the end of this session as the students who had opened the programs quickly were quite obviously the ones that then went on to read the game instructions and complete the task. The other students struggled throughout and two failed to get both programs open and ready to go. In this session almost all students completed the coins although some had become a little frustrated with the concept of creating new workplanes and new sketches. A successful lesson but not as much as the first one.

Lesson 3

I felt quite unsure as to how this lesson would go but my mind was immediately put to rest when all students came in, looked at the board for the instructions, followed them and opened the two programs successfully. The whole aura of the group seemed so much more relaxed than the previous lesson. They now knew how the game instructions worked and they were more aware of the *ProDesktop* software and how it worked. The main problem today seemed to be that some of the pairings were showing signs of cracking. This problem was mainly confined to the male pairings with accusations about 'not reading instructions out properly' or 'not listening to what I'm saying'. It turned out in one case that one half of the pairing had severe literacy problems and was unable to read the instructions. It may have been better if this student had spoken instructions or worked with a teaching assistant; unfortunately one was not provided for this lesson. The girls on the other hand excelled particularly in this session completing three tasks, the box, the bottle and the cork, in one go.

Lesson 4

This lesson saw the students working on the helix to begin with. Strangely, although this appears to be one of the more difficult looking shapes it is actually the one that no student has struggled with and it also seems to give them a lot of pleasure as it is so unusual. From there they moved on to the chalice. By now the students are not showing any signs of being phased by what their task is and are keen to move on. They are therefore obviously very distressed by the fact that they don't seem to be able to revolve the profile of the chalice. Some of them have not ensured a straight line for their axis which, once altered seems to solve the issue. Others have not checked the 'common problems' instruction sheet and have not added the extra piece of axis at the top. I believe that one of the reasons for the students missing adding an axis is that the video clip jumps a bit at this point. Once these problems are ironed out, the majority of the group were able to complete the task.

Lesson 5

Most students were set to tackle adding the gems onto their chalice. Some had not saved their chalice successfully and therefore had to redraw it quickly before continuing (they seemed to manage this with few problems). There were one or two issues with adding the gems and the main one seems to be that the students still do not actually understand the concept of what a workplane is or does. They know how to get a new one and how to move it but many moved it into the wrong position therefore causing a problem when trying to extrude the gems. It did not take long to sort the problems and a number of students were able to spend half a lesson working on their castle design. I showed them the examples on the help sheet and they were stunned at the thought of having to create something that complicated. They rose to the challenge, however, and with a little help and encouragement they made a very confident start.

Lesson 6

The objective today was to complete a drawing of a castle. Some students had started this in the previous lesson and were well on the way, others were starting from scratch. The separate instruction sheet guided the students through the early stages of the drawing and most of them that started today chose initially to stick to the layout on the instructions rather than attempt their own, more creative idea. Although quite a frantic lesson it was also very rewarding to see such a high level of outcome bearing in mind the students had only had 5 previous lessons. Teaching them about using the Album aspect of the program was a little 'on the hoof' but it was something that all the students using it picked up extremely quickly.

The final lesson asked the students to write an evaluation of their work as in the previous studies.

Appendix 13 Teacher diary – Study 4B

The teacher in this study kept a diary that was more conversational than the diary kept by the teacher in study 4A. It provides an insight into the teacher's fears and questions as the programme of study progresses.

Lesson 1

The fact that I'm writing this means that today, the day I have been dreading has arrived. It seems silly that the thought of 50 minutes of teaching can put such fear into a man's heart. You see I don't have a problem with the thought of teaching IT other than the normal concerns about whether the school server is up and running, the computers are working and of course there's always one student who has forgot their password. No, it's the thought of working with *ProDesktop* ... again.

They spent hours trying to teach it to me at Homerton (Homerton College, Cambridge). Since then, Homerton teacher training students have tried to teach it to me on their placements here.

Department staff have been away on courses on how to teach it and yet still none of us can. Or at least we can until something goes wrong and we can't troubleshoot the problems for the students and neither can they for themselves. The software has no credibility with us at all so why should it change now? It's like going into a lesson knowing you are going to teach the student from hell.

How did it go? Well to be honest, not too bad.

I did an intro: told them that they were the first students to use this software; that WE were going into uncharted territory (good move there – just to let them know that I know as little as them when it all goes pear-shaped); showed the teaching software on the OHP and outlined what they would be doing over the coming weeks. I gave a hand-sketched demo of how to convert a 2D object into 3D (by dragging it up off the paper to get over the basic principle of CAD) and then *with that knowledge, asked them to* complete the questionnaires. So far so good, now for the tricky bit – getting them to work in pairs.

I never like saying who works with who as they know the class chemistry better than me and I find similar ability students tend to pair up with each other.

There are 20 students in the class and I decided to teach it with four mixed gender pairs and the remaining in same-sex pairs. Four volunteers from each gender were asked for. Interestingly they wouldn't pair themselves and asked me to do it so I did it on the basis of height (wonder whether little people are more able than big people?).

I did an OHP demo of how to access the software and let them loose on the computers with about 15 minutes to go. All managed to see it and I just asked them to browse through the PowerPoint, which most did, but interestingly some students couldn't resist going for Google Sketchup.

I wonder whether their experience of this helps them with *ProDesktop*?

Now the phoney war is over. Next week we start in earnest.

Lesson 2

I got all the students to sit in their pairs from last week, gave them a quick overview and then a bit of a reminder as to where to find the games software. Eureka – they remembered so let them go.

Bit hacked off that four of them couldn't access the videos on their PowerPoint so logged on as me (broke the rules but for some reason it worked – there is a God). Students were very enthusiastic and focussed and generally worked well in their pairs.

In the rush to start they didn't follow the video so there were plenty of students getting nowhere. Enter wizard Dunkley with his book of magic spells.

There was no point in giving these out beforehand as they wouldn't have read them and anyway if you haven't made the mistakes yet what do you want them for?

Stopped everyone and a quick overview of the problems and how to overcome them (read the magic book of spells). Clear what you were doing and start again. I am a big believer in letting students make mistakes (well ones that I can sort if they go wrong – which I can't these so was chancing it a bit).

Looked at the clock with 15 mins to go and could see shapes that resemble keys but that was when the grief struck. 'It won't extrude' – 'No it won't will it' – three lines from a point or overlapping lines. Well I could see no three pointers, we'd given the shape a number one and trimmed off the sticking out bits so it must be overlapping. How the hell do you see those? Tell you what, you're an expert now so just do another and we'll see how that goes.

But lo and behold at the other end of the room 'I've done it sir' and another!

In the last couple of minutes we ended up with nine of the eleven pairs achieving the lesson objective. I'd have settled for less.

The question now is how do I manage next week's lesson with those people who didn't get there. I think I'll probably split them so that I can work collectively with that group while I leave the rest to move on under the guidance of my Year 12 helper – Josh.

Now here's something interesting. Josh was in my Year 12 lesson before this one in which I had given an intro into *Solid Works*, which I teach to the Year 12 students, so I asked him what he thought of that lesson and what they were doing. He said he found it quite helpful as it helped him to make more sense of what we had been doing with *Solid Works.*

On reflection, it wasn't a bad lesson. The kids were good and all achieved – even if it was only sketching a 2D key. I think I managed to put all my prejudices behind me with plenty of positive spin.

That said, it is frustrating when I can't see what is wrong. If it is overlapping lines, why don't they show up in a different colour and I know you told me to look out for lines going to the edge of the ellipse rather than the middle of it and I couldn't remember how to overcome it. There should be some help rather than hearsay. So far teaching methodology one, still Pro D none.

PS Have just realized I should have used my book of spells, it explains everything!

Lesson 3

Well what a lesson today's was!

This lesson a Martian landed in my room and locked himself out of his spacecraft so I got the class to tell him step by step how to design a new key using our OHP or rather showing *ProDesktop* on the OHP. They were really good, we only went up about three blind alleys and it was a really good opportunity to review the problems we had last week and how to overcome them. This is a method I use a lot with my younger groups and always seems to work well.

Anyway, after this they all hit the computers on a high which was added to by the fact they were given their grades for their first project and also passed on your comments that things were going well with them. What do you know? Everyone had produced a key by ten minutes into the lesson and was moving on to coins which again seemed to go reasonably well except for the few pairs who don't have the patience to follow the instructions.

The main problem was giving students marks – getting around them in time. Gave everybody an 8 today for strength as they had all had the benefit of the lesson intro but the creativity was really good with most students having the confidence to introduce non-linear shapes into their designs which then went into the coins.

How much impact is it having on the students? As we walked into the room a couple of them asked 'Are we Zasnooing today sir?' and were excited by the positive answer.

Lesson 4

Well the Friday before Christmas isn't the best time to be teaching anything, especially P4 just before lunch. It was the first time I had had students going off task and visiting our friends at Google! Needless to say progress was ad hoc but at least we all made it to the end of the lesson in one piece! All students achieved some work although it wasn't as creative or as smooth running as it had been in other lessons.

Lesson 5

Started the New Year with a reminder of what went wrong before Christmas (elephants have long memories) and then moved on to creating bottles and corks with a manual demonstration on the board. I find this quicker and easier than demo-ing on the software as I'm only interested in getting the concept across of how the software joins up a series of different shapes and there isn't a projector in the room.

The students found it quite straightforward to do and by the end of the lesson 75% had completed bottle and cork. Those that hadn't were the ones who had been unable to read and follow the instructions and tried to plough their own furrow. Isn't this a key feature of learning that I don't hear spoken of very often – a student's ability to listen and follow instruction? With all the support in the world, if they can't do this then learning is difficult.

Time is starting to run out now so I intend doing the chalice this week then going on to the castle. I don't know how long that will take.

I suppose the next question is 'where do we go from here and what role can this software play in the future'. Thoughts on that next week – saddo that I am, I have been thinking about it.

Lesson 6

The students struggled with this. Only something like a third of the class managed it and interestingly some of the highflyers from previous weeks were in the two-thirds.

In the intro, the students readily worked out the concept of rotating around a central axis as a means to completing the task but when it came to the real thing I think they were beaten by the subtleties of the program. We bypassed the gems due to the lack of time available and those that were successful (or just plain lucky) went on to render their work.

Lessons 7–8 The castle

When the students came into the class they were wowed by the edifice I had sketched on the board! When I told them that is what they were going to do they quickly shut up! Anyhow we got talking and quite soon they were into it using words like loft and extrude – it was quite humbling really as between them they were able to identify and describe the operations they would need to do to create this castle.

I told them they would be working independently on this one with no access to the video help, although they did have the help sheet. That is where the problems started. The three or four very able could loft the grass bank. While the rest of the class could extrude from a basic shape to create walls and towers while one or two managed to cut out a few windows. As a test – it appeared that they couldn't recall a lot of the processes.

This week was the last week I can give to the project but unfortunately I was off ill so they were thrown to a cover teacher, but they did have their regular sixth form support. I reverted back to them working in pairs, with one student having access to the video and having looked at the work they e-mailed me – they seem to have made some progress from the previous week.

For my part I think this is a very good concept for teaching students CAD. It gives them quick access to techniques that they can use successfully within the direction of the story. As with learning any sequencing, be it this or the words of a play, the more there is to remember, the more difficult it is to retain and it is interesting that the students retained more of the early input than the most recent lessons.

To learn CAD in my opinion, there has to be a purpose in doing the work set and the story line did just that.

I think this approach could be applied equally well to *Solid Works* or any other form of IT package come to that.

I believe its strength lies in the independence the students have to stop the video and wind back if you are not sure of what you are doing or using the sheets to sort out their own problems rather than having to rely on a teacher demo and then be thrown to the wolves!

As you said, I can't see it appealing to older students but for me the question is where do you go with it from here? These students will not encounter CAD for probably another twelve months and the likelihood of retaining a working knowledge of the software is low. I could see this being used with all the storyline stripped out as an online help for students in subsequent years. One thing that the package does do is make the students independent learners and it was quite refreshing to listen to their discussions about where they had gone wrong and what they would need to do to sort it.

For my part, I'm afraid it did little to put *ProDesktop* in a better light as borne out by the number of times I had to go for the quick fix of 'Let's open another file' when I couldn't see where they may have gone wrong. However, I did become much more confident as I had places I could turn to if I needed to.

It has been a good experience for the students as they have been telling other members of the department how they have been enjoying the work.

For me it has made me think about how I teach CAD with my year nines using solid works.

I start them off by getting them to follow the on-line tutorial. As ever the weaker students can't follow the instructions so I have paired them up and got one to instruct from the tutorial while the other carries out the task with quite a bit of success.